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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTION OF BRITISH FOUNDRYMEN AND THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION.

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NOTES AND COMMENTS.

Bending Strength of Cast-Iron.

It is well known that the ordinary formula for maximum fibre-stress in a cast-iron beam gives results very different in many cases from a direct tensile test taken in the ordinary way on the same material. Mr. J. H. Billing, in the "University Toronto School Eng. Bulletin," gives the results of some experiments made to determine the "rupture factor"—*i.e.*, the modulus of rupture as computed, divided by the unit tensile strength of the material as determined by direct tensile test.

Eight sections were chosen, comprising square, rectangular, and I-shaped beams, the latter being of two kinds—(1) with tension and compression flanges the same, and (2) with the tension flange thickened. To ensure uniformity all the beams were poured from the same ladle, and chemical analysis showed satisfactory uniformity. The tensile tests were made on an ordinary machine, and the beams were broken on a machine of somewhat larger capacity; no span was less than nine times the depth of the section. Half of the rectangular beams were machined all over, but no appreciable difference was noted in the final result. These may be summarised as follows:—

Shape of Section.	Rupture Factor.
Rectangular	1.5
Round	2.0
Uniform I-beam	1.2
Non-uniform I-beam	1.0

It will be seen, therefore, that the fibre-stress computed by the ordinary formula for a beam of I-section with the tension flange thickened is the same as that which would be got from a direct tensile test; while for a round bar the actual tensile strength would have to be doubled to arrive at the figure which the beam formula would give. The two I-beams were so proportioned as to have the same area.

We reproduce this abstract as we find it in the April issue of such "Abstracts" published by the Institution of Civil Engineers. As the Bulletin from which the abstract under review has been made has not reached us, we are unable to say whether the original author is responsible for the "poor show" or whether the abstractor has spoilt the Paper *en route*. There are hundreds of cast-iron girders still in commission in this country, doing useful work in carrying roads over railways, canals, etc., which have been designed with a cross section like that shown in Molesworth. Merely thickening the bottom flange of a cast-iron girder is of no use, as the flange has to be made considerably wider than the top flange. Theoretically, an inverted T-section would suffice, but a top flange is added for the sake of lateral stiffness.

Next, the late Sir Benjamin Baker, a former President, has read a very useful Paper before that self-same Institution on "The Practical Strength of Beams," in which he stated that he found that a rectangular section gave 1.70 times higher results in bending than in direct tensile tests, and suggested a correction for beams of different sections. Evidently Sir Benjamin's formula is not known in far Toronto, and we would therefore suggest to his abstractor to be more explicit as to what Mr. Billing has exactly done, and then to tell us how his results bear out or otherwise the Baker formula. Nothing is said in the abstract about deflection. Sir Benjamin showed the working of his formula on a steel rail. Cast iron may require a different treatment, owing to the great difference in its compressive and tensile strengths.

In Germany bending tests are generally carried out with round bars, in this country with rectangular bars.

The British Cast-Iron Research Association.

We have received from the Secretary of the Association a brochure setting forth the constitution, objects and activities of this organisation. The Association is to be congratulated on the effective, yet concise, manner in which it has put forward the *raison d'être* for its existence. Two very important points which the foundries will welcome are dealt with under the heading of "Work of the Association." The first allows of the conducting of research for a firm or groups of firms, which will be carried out confidentially for their exclusive benefit at cost. The second is a provision under which any research work which is being undertaken, and which is liable to damage the business of any member, the question of the continuation of the work will be immediately submitted to an independent arbitration for decision as to its continuation. Included with this pamphlet is a detachable application form for membership

XUM

The Prize Winners in the Foundrymen's Competition.

Mr. L. Tibbenham,

Winner of the First Prize.

Mr. Tibbenham, who is the managing director of The Suffolk Iron Foundry (1920), Limited, is no novice at designing foundry buildings, and more than one large foundry has sought his advice. After serving his apprenticeship at Messrs. Ransomes, Sims & Jefferies, of Ipswich, Mr. Tibbenham joined Messrs. Ruston, Proctor & Company, Limited, as chief tool draughtsman in the designing shop. After managing for some time a small agricultural implement works at Stowmarket, he

Mr. L. Tibbenham,
Winner of the 1st Prize in the Foundrymen's Competition.

purchased the foundry portion of the business. Under astute management this business prospered, but it was handicapped by inefficient design and its distance from the railway. It was in 1919 that Mr. Tibbenham built the foundry, the design of which gained the first prize in the Foundrymen's competition. In addition to this, Mr. Tibbenham, to use his own words, "resurrected" a small electric manufacturing concern situated near his works. This was so successful that after four years' running it was acquired by the Agriculture and General Engineers, Limited. Mr. Tibbenham, who is an Associate Member of the Institute of Mechanical Engineers, is well known as a foundryman. One of the specialities he has developed is the manufacture of cast-iron welding-rods, but the majority of his manufactures take the form of electrical machinery castings.

Mr. H. Lewin,

Winner of the Second Prize.

Mr. H. Lewin, who is at present engaged at the Sheepbridge Coal & Iron Company, Limited, was born in 1890. He was apprenticed to Messrs A. & W. Smith, Limited, of Glasgow, and The Stanton Ironworks, Nottingham. The theoretical side of his education was not "spoon-fed," for it involved his reaching home from the Nottingham University College evening classes toward midnight, and at that period apprentices worked from six in the morning to five at night. The result of

Mr. H. Lewin,
Winner of the 2nd Prize in the Foundrymen's Competition.

this work was the recommendation for the filling of the position as estimating draughtsman to a small firm of engineers and ironfounders, which he left after some two years to take up his present position. He is an Associate member of the Institution of British Foundrymen, Sheffield Branch, who have sent him the congratulations of the President and Council.

Queries Answered.

The Use of Borings in the Cupola.

C2.—With reference to "Omo's" inquiry *re* above, it is not at all necessary to use lime or water before briquetting. I have seen a large amount of this work done and any small scrap, such as millings, borings, turnings, or punchings, can be briquetted by a simple plant which pays for itself several times over. Briquettes have a very definite and promising future in foundry practice. In no way do they injure the product of the cupola, but their use effects economy both in material and time. "Omo" will find that the low price of borings in the briquetted form as compared with the cost of heavy iron scrap will surprise him. —T. V.

Solid Solution of Oxygen in Iron.

By Dr. J. E. Stead, F.R.S.

With the advent and use of the cupric reagent of Rosenhain and Haughton, Stead, Whiteley, Humphrey, Le Chatelier, Dupuy, and others, the micro and macro study of the structures of iron and steel has passed into a new phase, and evidence is accumulating that many solid solutions of iron and every other element are electro-positive to pure iron. The author's experiments appear to indicate that:—

(1) When iron is heated in air or oxidising gases, apparently the surface layers absorb oxygen which passes into solid solution.

(2) When supersaturated the oxide falls out of solution, forming separate globules of free oxide. These globules then become larger and larger as oxidation proceeds, eventually joining together to form continuous layers.

(3) Oxidising gases find the most facile passage into the steel between the crystals. The gradual changes from solid solution to free oxide can be clearly traced along the oxidised junctions.

(4) Sulphur, possibly as sulphurous acid (SO_2), in the gases penetrates into the body of the crystals, producing sulphide of manganese and possibly protoxide of manganese, which appear in globular form.

The British Cast-Iron Research Association.

A pamphlet has recently been published by the Research Association, of which the following is an abstract :—

Objects of the Association.—1. To promote co-operation amongst firms engaged in the various allied industries connected with the production and utilisation of cast-iron in Great Britain, with a view to the establishment of a scheme for scientific and industrial research.

2. The distribution amongst its members of technical and other information relating to the production, treatment, manufacture and utilisation of cast-iron. This necessitates the efficient co-ordination of the existing means of research and their further development.

The work of the Association will include the investigation of problems arising in the manufacture of pig-irons, grey-iron castings, malleable-iron castings, semi-steel castings, chilled rolls, cast-iron holloware, cast-iron pipes, light castings, etc., in such a way as to cover and include all branches of the cast-iron industry. Successful and economic production of these materials are very intimately bound up with the questions of melting, annealing, furnace design and construction, refractory materials, moulding sands, the economical utilisation of fuel, and the engineering aspect of foundry work. All these and other subsidiary operations will be dealt with by the Association, either directly or in collaboration with other Research bodies.

It will be appreciated that the investigation of these problems should place in the hands of foundry proprietors, pig-iron makers, and others the means of producing by more economical methods, thus reducing the cost of manufacture and of effecting improvements in the quality of the product. Such a result is of immense interest and benefit to both manufacturers and users of pig- and cast-iron in all its forms, and it is on these grounds that the Association makes its appeal to all engineering manufacturers, because there is probably no material which is more essential to modern civilisation than cast-iron.

Constitution and Management of the Association.—The Association is controlled entirely by the industry itself, subject to the statutory and other duties imposed upon the Association by the conditions of the Government Grant. The management of the Association is vested in a Council of not more than 36 and not less than 24 members, being representatives of members being Corporations.

All members of the Council must be either ordinary members or trade members of the Association, and are elected annually by the members, except such members of the Council who are co-opted by the Council. The first Council consists of the signatories of the memorandum and articles of association, and it has also been agreed that the Department of Scientific and Industrial Research shall nominate three members of the Council.

The Council will be representative of Labour and of all interests in the industry. For detailed work it will appoint an executive committee from its members, and will also appoint Research and Education Committees on which persons of practical knowledge and experience will be co-opted. The Research Committees will represent all sections of the industry, and different localities, and special care will be taken to represent all interests.

The Director of Research.—The organisation and supervision of the research work undertaken by the Association will be entrusted to a Director of Research, possessed of very high qualifications. He will be responsible to the Council for the carrying on of the whole scheme of research, his sole object being to serve the interests of members.

Work of the Association.

The work of the Association will be divided under three headings :—(*a*) Research Work; (*b*) The Bureau of Technical Information; (*c*) Education of Employees.

Research Work.—A very considerable amount of research work on foundry and cast-iron problems is proceeding throughout the world, but the results of such researches as have been conducted in foreign countries are not readily available.

It is the object of the Association to collect such data as shall be useful to the ironfounders of this country, and, wherever necessary, to encourage further research on definite lines as suggested by the work already carried out. Such a survey of the field of research must prove of immediate benefit to the members of the Association, and the co-ordination of the results of research completed up-to-date presents, possibly, the first opportunity of usefulness in the work.

It is hoped and expected that members of the Association will assist in the framing of a thoroughly comprehensive scheme, and, wherever possible, add the results of their own experience and research to the records of the Association; it is of vital importance that suggestions relating to their own particular section of the industry—so often connected with the peculiar needs and conditions of their own district—should be made by members themselves. It is realised that from this source much of the important future work of the Association must emanate.

Research, to be useful to the cast-iron industry, must proceed in many cases along lines suggested by practical difficulties or failures encountered during the manufacture, after manipulation, or use of castings.

The Articles of the Association provide for the following benefits and privileges to members accruing from research work :—

All members will have equal rights to the results of all general researches, but provision is made to prevent, where necessary, the business of any member suffering through the disclosure of results to non-members.

In addition to the co-operative research for the common good of members of the Association, provision is made for carrying on any investigation at the request of any individual member, or group of members, at their own cost, and for their own exclusive benefit. This provision will enable foundries who do not possess a laboratory, or who have only a small routine laboratory, to secure the assistance and advice of the best possible character from fully-equipped laboratories. The Association will thus encourage small foundries to group together and co-operate in having investigations made of problems which are of common interest and of mutual benefit to their own particular class of work.

An important provision is made whereby any member who considers that any work which is being undertaken by the Association is likely to damage his business can appeal to the Research Department, who will at once decide, after an independent investigation, whether the work shall be continued or not.

Arrangements will also be made to conduct experiments in foundries themselves, so that full knowledge of the principles underlying the various processes can be obtained. The Council fully realise that the value of research is frequently lost to manufacturers because of its lack of practical application. Hence every effort will be made to conduct the research work of the Association in such a manner as to enable the full value of the investigations to be infused into works practice. Obviously, in order to derive the full advantages of the improvements suggested by each investigation, the ready co-operation of all parties concerned with its application will be necessary, and should be encouraged.

It is not intended at present to incur any expenditure in providing laboratories for the Association, but to utilise for a time the laboratories in various parts of the country, and to carry out the work in whatever district any investigation is required.

The Bureau of Technical Information.—Obviously some time may elapse before there are any considerable fruits to be obtained from the research work, but no time is being lost in establishing at the offices of the Association the Bureau of Technical Information. Every foundry proprietor has day-to-day difficulties upon which he spends time, trouble and money in overcoming. In many cases the knowledge needed to overcome the difficulty exists, but is not commonly available. For this reason a Bureau of Technical Information will be organised for the benefit of members, wherein will

be collected, abstracted, and indexed all the world's literature and data upon foundry work.

To this Bureau any member may send his technical and other difficulties which he may encounter in his works, with the absolute certainty that if the knowledge he needs is available it will be supplied to him; if not available, and the matter is of common interest, every attempt will be made to obtain it for him.

The Bureau will keep a general subject catalogue of the literature upon foundry work as published, and will also establish a technical library of such literature for the use of the members. To this end the technical periodicals and journals of scientific societies bearing upon foundry work will be regularly examined, and all information relative to foundry operations abstracted and indexed.

The Bureau will collect information and data upon the best foundry practice in this and other countries, and place such information at the disposal of the members. A mass of valuable practical information is stored up in the experience of many workers in British foundries, and wherever this is offered it will be collected, systematised, and made available for the use of the members.

Members are invited to make use of the facilities which the Bureau affords, as it is hoped to make it the most comprehensive collection of foundry literature and practical information extant. Members and technical societies are asked to assist to this end by presenting to the Association British or foreign technical papers, or periodicals and society journals.

(*c*) *The Education of Foundry Employees.*—As it is recognised that there is a dearth of recruits in the foundry industry, and an ever-increasing difficulty during prosperous times in retaining young workers in the foundries, a comprehensive scheme of propaganda is necessary, whereby the interesting and scientific character of foundry work may be placed before the youth in our industrial areas.

It is obvious that efforts in the direction of a general improvement in the conditions of working within and about foundries. "Safety-First" work, and a furthering of all reasonable and rational methods to secure hygienic environment must exercise the mind of every foundryman. The Association, in its desire to encourage and improve the education of persons engaged, or likely to be engaged, in foundry work, has appointed an education committee, whose duty will consist in consulting with the educational authorities in various parts of the country, and make recommendations as to the courses of study in foundry work to be pursued in technical schools.

What the Association can do.—This section has been dealt with in a Paper by Mr. T. Vickers on the Co-operation of Scientific Research in the Foundry, which was published in the March 31 and April 7 issues of THE FOUNDRY TRADE JOURNAL.

Advantages of Membership.—The benefits and privileges of each firm joining the Association, as provided by the articles, are as follow:—The firm will receive the results of all researches carried out by the Association for the common good, and a regular service of summarised technical information relating to the industry at home and abroad. It will be able to obtain a translated copy of any foreign article in which it may be specially interested, and will have the right to put technical questions and to have them answered as fully as possible within the scope of the Association. It will have the right to recommend specific subjects for research, and if the Council consider the recommendation of sufficient general interest the research will be carried out without further cost to the firm, and the results will be available to all the firms in the Association, and, subject to the articles of association, to the use of any patents or secret processes resulting from all researches undertaken.

Specific research will be undertaken for its sole benefit at cost price.

No firm outside the Association will have any of these rights. The documents and bulletins available for members will not be published unless the Council of the Association decide that they shall be.

Membership.—All British firms who are engaged in any branch of the cast iron industry, whether producers, manufacturers, or users, are invited to join the Association.

The membership of the Association consists of persons and corporate bodies with the following status:—(*a*) Ordinary members shall be British subjects or British companies carrying on business in the production or treatment, utilisation or marketing of cast iron. (*b*) Trade members shall be British subjects or British companies carrying on business in the production of machinery, appliances, plant, apparatus, accessories or materials to be employed or used in connection with the cast iron industry. (*c*) Associate members must be scientific workers, pressmen and others connected with the cast iron trades or industries, or likely to assist in the development of the same in any part of the world, or superintendents, directors, secretaries, or other officers of limited liability companies carrying on such business. (*d*) Delegate members are delegates of other British Associations or Institutions established for the purpose of promoting the application of science to industry. (*e*) Honorary members will be elected by the Council for special services or for special cause.

All ordinary, trade or associate members must be British subjects or a corporate body registered in Great Britain or Ireland.

Subscriptions.—Every ordinary member undertakes to pay to the Association an annual subscription or assessment based upon the number of persons engaged in his foundry, and to agree, in writing, to continue to pay the subscription for a period of five years from the date of their election. This provision is absolutely necessary to ensure stability and continuity of the work. The conditions of the subscription are as follows:—(*a*) The subscription is based upon the number of persons employed in the iron foundry business of the member. (*b*) A differential basis is adopted and may be continued as the Council shall determine for any of the following:—Manufacturers of cast iron, malleable cast iron, and pig-iron, and for trade members. (*c*) In ascertaining the number of persons employed all persons who are actually employed in the production of iron castings or malleable iron castings, or both, are included, but no account shall be taken of pattern-makers, warehousemen, clerks or travellers. (*d*) Ordinary members will make, during the month of January in each year, a return in writing, to the Secretary of the Association of the average number of persons employed in one or both of the industries above specified during the preceding three months. All such returns will be regarded as confidential by the Association. (*e*) The annual subscription will be at the rates following:—

1. *For members employing the following number of persons in the manufacture of iron castings.*—Not exceeding 25, £5 5s.; exceeding 25 and not exceeding 50, £10 10s.; and exceeding 50, for each additional 50 employees or portion thereof, £5 5s.

2. *For members employing the following number of persons in the manufacture of malleable iron castings.*—Not exceeding 25, £5 5s.; exceeding 25 and not exceeding 50, £13 2s. 6d.; and exceeding 50, for each additional 50 employees or portion thereof, £6 11s. 3d.

3. Members engaged in the manufacture of pig-iron and also trade members will pay such annual subscription as shall be arranged between the Council and such members. In every class of membership the minimum annual subscription will be £5 5s.

In the case of any member whose business is not wholly connected with the production, treatment, utilisation or marketing of cast-iron or accessories thereto, the Council may levy such assessments as shall be arranged between the Council and such member. Honorary and delegate members do not pay any subscription. Associate members pay such subscriptions as the Council from time time decide.

Income-Tax.—An important point has to be remembered, that all subscriptions paid to this Association are recognised by Surveyors of Taxes as business costs of the contributing firm, and are, therefore, not subject to income-tax or excess profits taxes, so that the net cost to a member is comparatively small.

The Welding of Steel in Relation to the Occurrence of Pipes, Blowholes and Segregation.*

By H. Brearley (Sheffield).

(Slightly Abridged.)

It is well known that perfectly clean surfaces of malleable metals will stick together under pressure at temperatures much below those commonly used for welding. Platinum is a case in point. As that metal does not readily oxidise, worn vessels can be easily repaired by hammering a piece of hot sheet platinum over the defective part. Hot steel can also be welded together under pressure at low temperatures in an atmosphere of hydrogen or other inert gas. Turnings sometimes stick to the cutting edge of tools which are doing heavy work, and it is on record that a cutting tool has been found welded to a heavy forging which was being machined.

Steel oxidises at comparatively low temperatures. The temper colours visible on bright steel heated up to 200 deg. C. and beyond are forms of iron oxide which, as the temperature is raised, pass gradually into the more or less adherent oxide of measurable thickness which we call scale. The scale thus formed is a brittle substance whether hot or cold; it is not malleable or plastic, and cannot be welded together. At very high temperatures the scale melts and could be expressed in the fluid condition from between two metallic surfaces, but the temperature at which it remains sufficiently fluid is near the melting point of steel. At such high temperatures the fluid oxide scale reacts with the carbon of the plastic steel, liberating carbon monoxide, or dioxide, which forms blisters. It is, therefore, not practicable to make a respectable weld without using some means of lowering the melting temperature of the scale, and also modifying its oxidising effect on the hot steel.

In order to flux the scale which forms on heating iron and steel, the blacksmith uses sand. The sand-scale slag thus formed should be such as is fusible at temperatures some hundreds of degrees below the melting point of either the scale or the sand. Its fusibility varies with the respective proportions of scale and sand used. Too much of either constituent produces a less fusible flux. Since the amount of one of the constituents—the scale—cannot be determined, the most effective quantity of sand to use can be selected only by skilled judgment; it depends on the amount of scale needing to be fluxed, and the area to be covered by the fusible sheath which cleans the surfaces and shields them from further oxidation.

Being produced under empirical conditions which are so difficult to control, there is no wonder that welds apparently similar are really of varying quality. The best of them are never perfect, though statements to the contrary are frequently made. A weld may appear under certain test conditions to be stronger than the adjacent part, for two reasons: first, because the adjacent parts have been badly overheated and not hammered; and, second, because the welded part has been superficially carburised by the coke fire and to a corresponding extent that part has a higher tensile strength. Both these conditions are due to negligence, and hence, judging from the comparative behaviour of welded and adjacent parts under the stress of a tensile test, we arrive at this amazing paradox—the less skilfully the welding is done the better the weld may appear to be.

The tensile test is not a very satisfactory means of recording the weldability of a steel, or the efficiency of a welding process. Although all welds are more or less defective the position of the defect may be unknown, and consequently when a tensile test-piece has been machined it is a question of pure chance whether a particular kind of defect is in the core of the test-piece or on its surface. In the former position the defect may not greatly influence the test figures; in the latter position the test-piece breaks either before, or soon after, the maximum stress has been reached, and consequently the ductility figures are very poor. In the same way the tests made on gun-tube forgings, taken transversely, give very erratic results, due not to variations in the suitability of the material for its intended purpose, but to the occurrence of slag streaks haphazard, now in a favourable position, now in an unfavourable position in the test-piece.

How near to perfection a weld can be made is a question of great importance to steelmakers. Under rolling or forging conditions a steel may be unweldable and yet an ingot may be forged into sound bars. If, however, such an ingot be cracked, as more are than we like to admit, then it is not forgable, but will crumble under the hammer. This explains why of certain alloy steel ingots having the same composition some forge well and others not at all, or very badly.

Ingots are never quite free from shrinkage cavities, contraction cavities, cracks, or blowholes. It has been proposed that ingots should be made with a volume of deep-seated blowholes sufficient to neutralise piping and thus avoid the necessity of scrapping a discard head. As this method of avoiding pipe has been in use for many years it is fair to assume that such ingots produce billets, bars, and sheets which are commercially satisfactory for certain purposes. Dr. Stead and others conclude from microscopic evidence "that the welding of blowhole cavities as a rule is complete and perfect." Their experimental evidence is obtained by boring a hole into an ingot or billet, fitting a plug of the same material, sealing the joint with a blowpipe, raising to welding heat and hammering or rolling into a bar. If the bar, when nicked and broken across the welded faces, shows no signs of the weld, and the microscopic evidence be satisfactory, it is assumed that the weld has been perfectly made.

If by perfection we mean a welded joining which is in all respects as good as any unwelded part of the same bar, then it may be said that the evidence is insufficient to support the conclusion even so far as the limited experimental conditions are concerned. The conclusions are a still less satisfactory answer to the question whether blowholes in ingots weld up because a drilled hole is smooth and clean, whereas a shrinkage cavity or blowhole may be uneven, lined with segregates, coated with alumina, or otherwise less favourably disposed to weld completely.

During the war great trouble was caused by the occurrence in aero-engine crankshafts of small cracks, whose origin was camouflaged by calling them "hair-lines"; just as, ten or twenty years ago, slag streaks were called "sand cracks" and many other names except slag. The so-called hair-lines arose mainly from ingot defects, notably those occurring in and about the axis of the ingot. These axial defects are the remnants of shrinkage taking place in the nearly solidified ingot. The small volume of impure metal last fluid moves downwards as best it may between the loosely adhering free crystals, filling up shrinkage and contraction cavities as long as it is hot enough, or impure enough, to keep fluid. It is finally frozen in positions, lying like an inverted cone about the axis of the ingot. It is called a "V" segregate because it can be detected by a sulphide print, but the harm lies in the small cavities themselves rather than in the sulphide segregate found in, or near, the cavities.

The "V" cavities are greater when an ingot is cast hot than they are when the same kind of ingot is cast cold. The remedy is to cast cold in a mould tapered as much as is practicable. The remedy, however, does not get rid entirely of the cavities, and one must reckon that the remnants of them may appear either as split centres, if the forging be carelessly done, or as small seams or "hair-lines," however skilfully the forging operation may be carried out.

It has been suggested that minute defects inherent in commercially sound ingots, and small blowholes which may occur accidentally, do not

*A Paper read before the Spring Meeting of the Iron and Steel Institute.

weld up in nickel-chromium steels, because steel containing chromium will not weld. And it has been said that if aero-crankshafts, and other important structural components, were made from nickel steels or, better still, from carbon steels, the greater weldability of these steels would remove all difficulties. When this idea is tested under conditions more favourable than those occurring in practice, *i.e.*, by drilling holes along the axis of a bloom, inserting a machined bar of the same material, and after hermetically sealing the ends, rolling the bloom into a small bar, which is then nicked and broken, we arrive at very curious results. Some steels tested in this way were ordinary mild steels containing 0.15 per cent. and 0.35 per cent. carbon, a 3 per cent. nickel steel, a 5 per cent. nickel case-hardening steel, and a nickel-chromium steel, such as was used for aero-engine crankshafts. On etched transverse sections of the bars the weld lines were either not visible or slight indications only were discovered after much patient searching. When the bars were nicked and broken across the welded surfaces all the steels, judging from the fractures, appeared to have welded perfectly except the 0.15 per cent. carbon steel and the 5 per cent. nickel case-hardening steel. Unless, therefore, we are prepared to believe that tough mild steels weld less perfectly than nickel-chromium steel, we must question the reliability of both these methods of measuring the efficiency of a weld.

On hardening and re-heating the entire series of steels so as to put all of them into a tough condition having Izod figures of over 50 ft.-lbs., we find that not one of them withstands the nicked bar test; without exception they pull apart at the welded surfaces. These results explain clearly why transverse fractures of nickel steels appear to be more reedy than similar fractures made in ordinary carbon steel, *i.e.*, the nickel steel is tougher and therefore pulls open on the faces of welded blowholes, or slag streaks, more than in the less tough carbon steels; the steel itself is not more reedy in the sense that it contains more slag streaks, or less perfectly-welded blowholes.

It is obviously incorrect to say that steel containing chromium cannot be welded under such conditions as apply to the welding of cavities in ingots. If, however, we are seeking some means of expressing the extent to which such steels weld, as compared with ordinary carbon steel, we should endeavour to state comparative results in concrete figures. No attempt appears to have been made to do this. The method to be described is submitted for consideration in the hope that it may be improved, or a better method may be evolved. Some method, at any rate, is desirable if we are to explain the known difficulties in forging special steel and understand the effects of blowholes and segregates on the properties of steels containing them.

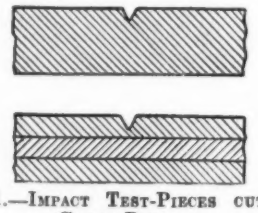


Fig. 1.—Impact Test-Pieces cut from Cored Bars.

The steels to be examined are prepared as 3½-in. billets. A hole 1 in. in diameter is drilled down the axis of the billet, and a turned bar is driven into it and fused over at each end. The cored billet is then rolled into a bar 4½ in. by ½ in. Impact test-pieces cut from the side and centre of this flat bar may be represented diagrammatically as in Fig. 1. The test-piece cut from the side will be broken by a force recorded in foot-pounds which represents the effort required to start a crack at the root of the sharp notch and extend the crack across the specimen. The test-piece cut from the centre of the bar is broken in the same way, but it will require a somewhat greater force to extend the crack across the specimen, depending on the perfection of the weld between the core and inside of the hollow billet. If no welding has occurred the crack will come to a dead stop when it reaches the core or leaves it, and a new crack would need to be started in each case. This, as we know, absorbs a great deal more energy than is required to propagate a crack which has been already started.

Very hard steels have low impact values because the material in and about the notch is not able to distort, and such steels, even in the form of cored bars, break readily across whether the weld is a good one or not. Conversely, steels having low impact values, whether they are very hard or not, fracture readily across welded cores, and this explains the insufficiency of the nicked bar test as an indication of good or bad welding. To pull a weld apart, if it can be done, the material should be put into a tough condition. The proposal is to measure the perfection of a weld in terms of the degree of toughness which must be induced in the steel before the weld can be pulled apart.

A series of specimens cut respectively from the edge and centre of the flat bar, prepared as

Table I.—*Steel A.*

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
0.34	0.22	0.75	0.052	0.057

Treatment—Oil-hardened at 850° C. and tempered at degrees C. shown.

Degrees C.	Impact Edge. Ft.-lbs.	Impact Centre. Ft.-lbs.
none	7	18
100	4	5
200	9	12
300	3	6
400	12	20
450	28	48
500	44	111
550	50	120

Table II.—*Steel B.*

Carbon.	Silicon.	Manganese.	Nickel.	Chromium.
0.34	0.23	0.71	3.26	0.28

Treatment—Oil-hardened at 830° C. and tempered at degrees C. shown.

Degrees C.	Impact Edge. Ft.-lbs.	Impact Centre. Ft.-lbs.
none	3	3
100	6	7
200	17	16
300	4	4
400	20	31
400	24	32
450	23	41
450	25	70
500	39	120
500	39	104

Table III.—*Steel C.*

Carbon	Silicon	Manganese.	Nickel.	Chromium.
0.32	0.23	0.53	3.11	0.06

Treatment—Oil-hardened at 850° C. and tempered at degrees C. shown.

Degrees C.	Impact Edge. Ft.-lbs.	Impact Centre. Ft.-lbs.
none	6	15
100	10	10
200	18	53
300	6	8
400	30	118
450	31	120

Table IV.—*Steel D.*

Carbon.	Silicon.	Manganese.	Nickel.	Chromium.
0.35	0.23	0.72	3.57	1.05

Treatment—Oil-hardened at 830° C. and tempered at degrees C. shown.

Degrees C.	Impact Edge. Ft.-lbs.	Impact Centre. Ft.-lbs.
none	2	3
100	5	27
200	15	120
300	4	4
400	8	19
400	6	20
450	14	56
500	18	120
650	52	120

described, are hardened and tempered in stages of 100 deg. C. up to say 700 deg. C. These are broken on a standard Izod machine, and the impact value of the edge specimen whose corresponding piece cut from the centre is split along the weld is taken as the welding figure. The examples in Tables I, II, III, and IV will explain the working of the process.

From these results the comparative welding figure selected would be:—Steel "A" = 28 or rather less; steel "B" = 20; steel "C" = 18; steel "D" = 14 or rather less. That is to say, these figures represent in Izod foot-lbs. the degree of toughness which must be induced in the steels by hardening and tempering in order to pull the welded surfaces apart into a visible gap.

If instead of rolling into flat bars the cored billets are rolled into round, or gothic, or square bars, and tensile pieces are prepared from the bars which have been heat-treated to develop maximum toughness in them, the core will sometimes be visible in the broken tensile test-piece, and sometimes not visible. For microscopic observation a transverse section could be cut from the flat bar on which, if the welded faces were well defined, the core would be represented by the outline of an ellipse. The pointed ends of such an elliptical outline could be traced with more or less certainty in all the specimens, but it was more marked in the alloy steels than in the carbon steels. Nothing similar could be detected in the alloy steels in the rolled or hardened and tempered condition.

In order to increase the separation of ferrite in the carbon steel and promote its separation, if possible, in the alloy steels, samples of each of the four alloy steels were heated to 860 deg. C. and cooled down to 500 deg. C in nine to ten hours. Etched sections made from these specimens now showed a band of ferrite about the welded surfaces of all the steels except the nickel-chromium steel.

How far the proposed method of testing welded surfaces, or determining the coefficient of welding, will be found reliable and useful must be shown by further experiment. It is clear, however, that all forms of plastic welding such as are used by the blacksmith, and such as operate in the rolling and forging of piped ingots, produce welded parts unlike other parts of the bar, inasmuch as the welded surfaces can be pulled open, and the free ferrite about them is quite abnormal.

The appearance of free ferrite about welded surfaces recalls the occurrence of the banded ferrite structure in mild steel plates and bars. The banded structure has been ascribed to micro-segregation of phosphorus. On the other hand it has been suggested that non-metallic impurities in steel in the form of slag streaks, etc., act as nuclei around which the ferrite gathers as it falls out of solution, just as sugar-candy crystals form about a thread suspended in the liquor. Whilst the formation of free ferrite on the welded faces falls naturally into its place as a special instance of the effect of nuclei action, it is difficult to see how it can be related to phosphide segregation.

The conditions, described in the earlier part of the Paper, under which the coefficient of weldability is determined, are obviously empirical, and it would probably be necessary to adhere to given dimensions of billet, the inserted core, and the rolled flat bar in order to get consistent results. To observe the effect of deviations a 4-in. square billet was prepared with the usual 1-in. core, with a ½-in. core and with a ½-in. hole, the end only of which was plugged. In the rolled flat bar the welded surfaces would of course be a single one in the case of the ½-in. plugged hole, and double ones in the cases of the ½-in. and 1-in. cores. The welded surfaces would also lie variable distances below the bottom of the notch. The actual figures obtained both on softer and harder steels did not show great variations, and they were all in such directions as might be expected. The effect may be summarised by saying that when the hardened and tempered pieces are sufficiently tough to cause the weld to split open, the impact value obtained from the welded pieces depends on the thickness of metal behind the split weld which has to be bent by the pendulum hammer. Whilst useful information may be obtained whatever size of billet and bar is used, it is advisable to adhere to fixed sizes if the results are required to be strictly comparative. The author prefers to insert a core into the drilled billet, as then two welded surfaces occur in the impact test-piece.

Although we may be convinced that no pipe or cavity in an ingot can be completely welded, we need be neither elated nor depressed by the fact. It is no part of an observer's business to allow personal prejudices or commercial prospects to colour his views. An investigator's opinions ought not to be malleable under the stress of convenience. Besides nothing is wholly bad, and what may appear as a defect under one set of circumstances becomes an advantage under another. In this respect we may observe that the degree of imperfection of welds is made manifest by a rise in the impact figure. Were no welding to take place the impact test specimen used would bring the testing machine to a dead stop, although the material was not in a very tough condition. If, therefore, the material of a piped ingot, or a blown ingot, be stressed transversely to the direction in which it has been elongated by forging or rolling, such stresses carried to the point of fracturing will have more work to do than under similar circumstances would be required to fracture such material made from a sound ingot. The plate of a laminated spring is one of the best examples of the truth of this deduction, and as a matter of experiment it is found that a cambered spring plate made from the top of a piped ingot cannot be broken by scragging as easily as a similar plate made from the bottom end of the same ingot. In this sense blown ingots, or those rich in non-metallic impurities, make good spring plates, and it is mainly on this account that Bessemer steel is preferred by many spring-makers to the more carefully melted and cast open-hearth steel. To some extent the same advantages apply to straight axles, and they are worth consideration even in relation to rolled tyres. It is very remarkable that the fabled virtue of all good wrought iron, viz., its fibre, should be regarded as a defect in steel. It should be valued of course like the grain in wood, according to its direction, in relation to the stresses put upon it.

That pipe, or blowholes, or any other form of cavity in ingots is apt to be, and usually is, associated with segregated carbon, phosphorus, and sulphur requires no special proof. If, therefore, the discussion be confined to the welding of ingot cavities it would be instructive to know how far the cohesion of the welded surfaces is influenced by carbon, phosphorus, and sulphur respectively, and whether the influence of these elements present in the same specimen is additive or otherwise. A few statements on this subject have been made, but they must be regarded as opinions rather than as evidence. It has been said that "the welding up of blowhole cavities in ordinary practice is, as a rule, complete and perfect," and also that "phosphorus concentration in blowholes facilitates welding, and iron relatively high in phosphorus is more readily welded than very pure material." We must remember, however, that this conclusion depends either on microscopic observation which may be illusory, or on the nicking and breaking method which may be misleading. Of the two methods of judging a weld it is claimed that "nicking and breaking was a more certain method than that of the microscope." As the nicking and breaking method carried out on bars in the forged and rolled condition would lead us to believe that all hardening elements added to steel, including phosphorus, improve its welding properties, its results obviously need to be interpreted with caution.

It is generally stated, without any experimental warrant being adduced, that all segregates existing in ingot cavities decrease the weldability. It has been assumed that in the absence of segregates a perfect weld could be made, and as segregates and imperfect welds are often found together the presence of the segregate and the degree of imperfection are regarded as cause and effect. This conclusion is untenable now we know that perfect welds cannot be made even under the most favoured conditions.

In 1912 Dr. Stead prepared two crucible ingots containing 0.020 per cent. sulphur. One was blown and the other sound. Both were forged into round bars and parts of each bar were turned into annular rings. When drifts were forced into the rings those made from the blown steel broke with 50 per cent. less extension than those made from

sound steel. A sulphur print taken from the forged bars showed clearly the location of the blowholes, because segregates had been pressed into them by such forces as operate in every solidifying ingot. The weakness of the one set of rings as compared with the other was ascribed to the presence of sulphide segregates. Such a conclusion, however, is only justified if it can be shown that identical rings made from blown steel containing no segregated sulphide are practically as strong as rings made from sound steel. A direct experiment on these exact lines cannot be made because it is impossible to produce commercial ingots containing blowholes without these holes being more or less lined with segregates. But as the blowholes could not weld completely under any circumstances it is likely that the rings were weaker in one case than the other, quite apart from any question of segregation. To test this supposition a dozen small holes were drilled lengthwise to a depth of 8 in. into a 4-in. billet. Each hole was cleaned, dried, and filled with petrol vapour before being closed by plugs 1 in. long driven in with a sledge-hammer, and fused over with the oxy-acetylene blowpipe. The billet was rolled into a $\frac{7}{8}$-in. round bar. From the sound and unsound parts of the round bars annular rings were turned. The rings were drifted, as in Dr. Stead's experiment, until they broke, with the results shown in Tables V and VI: —

Table V.—*Steel A.* 865.

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus
0.46	0.15	0.70	0.040	0.030

Condition of steel	Percentage increase in diameter of drifted rings made from	
	"Unsound" part.	"Sound" part.
As rolled	2.4	14.5
,, ...	3.4	12.6

Table VI.—*Steel Y.* 339

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
0.15	0.23	0.92	0.060	0.018

Condition of steel	Percentage increase in diameter of drifted rings made from	
	"Unsound" part.	"Sound" part.
As rolled	2.7	20.8
,, ...	7.8	22.9

Sulphur prints were made from both the sound and unsound bars, but there was no distinction between them. These results appear to negative the conclusion that the annular rings in Dr. Stead's experiment broke prematurely on account of sulphide segregation; they would have broken prematurely in any case, because blowholes or any other cavity in an ingot do not weld completely however much work may be put on to the material during forging or rolling.

The difference in behaviour between the sound and unsound rings when drifted is a striking example of the disadvantages of blown or piped steel when stressed transversely. Gun tubes or gas cylinders are stressed more or less like the drifted rings, though they are, of course, not made into hollow tubes in the same way, and a welded blowhole would lie more favourably in either case than in the drifted rings. Gun tubes are not made from blown ingots, but blown ingots of mild steel are consciously made into billets and blooms for tubes and gas cylinders. Whatever commercial warrant there may be for this practice it would appear to be undesirable metallurgically, because blowholes induce spot segregates, and are undesirable mechanically because the incompletely welded cavity decreases the resistance of the steel to the working stresses.

There seems to be little doubt that sulphur has been blamed for defects due to other causes, and one wonders whether this segregate in particular is quite as harmful as it is made out to be. Take, for example, a pieces of boiler plate which has laminated on flanging. The metallurgist applies a piece of acidified photo paper and produces a sulphur print showing that the defective part corresponds with a segregated area. According to text-books segregates are known to be harmful and high sulphur is reputed to cause red-shortness. The inference is easy, but the obvious explanation is, in many cases, not the correct one. It is true that sulphur compounds segregate in steel; so do phosphorus, and so also do carbon compounds. Of these the one most easily detectable, and almost invariably detected, by the method of sulphur printing is sulphur, but it is not therefore necessarily more culpable than either phosphorus or carbon. Further, in perfectly sound ingots (except perhaps very large ones) mass segregation is not possible. In such ingots as are practically sound, that is to say, in the best type of commercial ingots, mass segregates are found only where there are, or have been, cavities. The pipe in a piped ingot is lined with segregates and most cavities in a blown ingot are distinguishable in the forged blooms by the segregates which filled, or partly filled, the cavities in the ingot stage.

On reconsideration of the laminated boiler plate we must regard the dark centre part on the sulphur print first as evidence that the ingot material from which the defective article was made was piped. The sulphide segregates enable us to draw this important conclusion, but whether the segregates as a whole have aggravated the defect depends on whether or not they have interfered with the chances of the pipe welding up. The facts are broadly the same with respect to spot segregates. In either case, that is to say, in relation to both axial segregates and spot segregates, the real cause of the trouble is either a pipe or a blowhole, and it is not reasonable to blame the segregate, which in the nature of things gets squeezed into these cavities, unless they interfere with welding. A series of five crucible steel ingots containing from 0.06 per cent. to 0.17 per cent. sulphur, but otherwise similar in composition, have been prepared in order to observe the influence of sulphur on the welding figure. The results are not ready for publication, but so far as they go they show that either in the rolled condition or in the hardened and tempered condition the high-sulphur steels weld as well as, and on the whole rather better than the low-sulphur steels. This, and general experience, lead the author to assume that of the segregates themselves, the least harmful, taking all things into account, is probably sulphur, By pure chance it happens to be easily detectable, and it is thus forced to turn king's evidence against its associates.

It would be something of a paradox if, presuming it could be entirely eliminated, sulphur were after all retained in, or purposely added to, steel in order to serve as witness. A sulphur print of an ingot section is one of the best records of the conditions under which an ingot is formed. It may indicate the casting temperature whether top or bottom casting methods have been used; whether blowholes later filled up have existed earlier in the partly fluid ingot: and many other useful things to the observant investigator. It is by far the most valuable means available for determining whether a forging became axially unsound on hammering or was made from piped material. It indicates at once the presence of spot segregates in forged or machined articles, and either facilitates the machining or suggests that the material should be scrapped, and finally it is an indispensable touchstone for the careful steelmaker who is making steel for such special purposes as rifle barrels. In nearly every case a sulphur print is less valuable as an indication of sulphur than of more harmful things of which its presence gives warning. A sulphur print is worth many sulphur determinations, and we could hardly spare the tell-tale sulphur altogether—we might then have to add sulphur to our steel as we know nothing so voluble, so reliable, and so harmless which would serve the purpose equally well.

Very few experienced observers will doubt the possibility of pulling apart welded faces in objects made from blown ingots. The author believes that it can be done, always providing the steel in which they occur is tough or can be made tough by heat treatment. Iron and steel lumps from which bars for machine knives are made are produced by casting very mild steel against the face of very hot tool steel. In the forged or rolled bar the interpenetration is considerable. The two materials, however, can be pulled apart along the original faces. Three-ply steel, such as is used for making plough mould boards, is probably produced in a

similar way, but the rolled sheet can be split and the iron core separated if the sheet be first toughened by hardening and tempering.

If a billet be drawn down at one end into a bar, the unforged part of the billet may be worked up and down in fluid steel as it rises in an ingot mould, so as to heat the billet and drive off adherent gases. Such a billet may then be left in the upper part of the ingot in a highly preheated and clean condition. After forging that part of the ingot containing the billet may be rolled into flat bars and such bars may be tested. After this procedure a core corresponding with the original billet section may always be separated.

From these considerations one would expect that impact test-pieces cut from the centre and from the edge of a flat bar rolled from an ordinary ingot would frequently give different results. Such differences actually exist, and moreover the difference is most marked when the bar is taken from that part of the ingot which is unavoidably least sound. An ingot cast wide end up and provided with an efficient feeder head is—omitting the feeder head—most nearly perfect in its bottom third and top fourth; it is less perfect in the centre of its middle half. These facts are clearly discernible in a sulphur print made from a sound ingot which has been sectioned longitudinally through its centre. Quite in accordance with the sulphur print indications one finds that variations in impact test-pieces cut from the edge and centre of flat bars are greater or less, according as the bars have been made from the middle or one or other extremity of the ingot.

Discussion.

The President remarked upon the importance of the Paper and said it was based somewhat upon previous work which he (the President) had done, but the author had gone one better. He had adopted better methods of determining whether or not blowholes and cavities in ingots were really welded up during working. He did not intend to discuss the Paper, but simply to point out how very important it was that it should be known definitely whether a clean cavity was welded up or not. Blisters were formed in steel where apparently nothing but gas existed; blistered sheets and blistered plates were very often met with.

Dr. J. O. Arnold, F.R.S., desired to ask the author, in the first instance, whether it was not possible to come down to first principles before dealing with details. The author had referred broadly to segregates, and had pointed out, very properly, that they might consist of the elements of carbon, phosphorus, and sulphur. In what form, however, did they exist? He thought the conclusion must be arrived at that an argument which would apply to a segregate of one of those elements would not apply to the others. It was known that an ordinary steel containing, say, 0.05 per cent. carbon, and 0.5 per cent. manganese, had a double carbide of iron and manganese; that, he thought, was not disputed. He quite agreed with the author that manganese sulphide, MnS, was not likely to weld with steel. It was perfectly plastic, as plastic as iron itself, but the MnS was always obtained in layers in the steel. Where those flakes of MnS occurred no very serious breaking was noticed. How did they act? Had they acted in the ordinary way as a mechanical mixture where there was a fracture across every flake of manganese sulphide? He particularly asked the author to consider, in connection with the subject of fracture, the case brought forward for holding alloys like manganese sulphide in a strong position by means of surface tension. Those flakes could be recognised regularly with the microscope, and yet they were very firmly attached to the iron or mild steel surrounding them. What was holding them? He submitted it was necessary to explain more carefully those fundamental segregates and how they were acting in the mass, and in that connection he thought it was necessary to take into consideration the question of surface tension, so ably developed by his colleague, Dr. Thompson.

Mr. H. Dodo said that in the early part of the Paper the author had explained that one reason why a weld might appear under certain test conditions to be stronger than the adjacent part was because the welded part had been superficially carburised by the coke fire and to a corresponding extent that part had a higher tensile strength. But he would like to point out that it would be much more reasonable to use the term "yielding strength," instead of the term "tensile strength," because the effect of the supercarburisation in the welded part would give rather a higher yielding strength, as compared with the adjacent part. He would take an ordinary tensile test as an example and would like members to imagine a stress-strain diagram. Under the test the adjacent part would arrive at the yielding point before the welded part did. The adjacent part would be elongated under applied stress, and consequently the reduction of the test-piece would occur in that part. Therefore, the stress would be concentrated to the reduced section and would break at that point in the adjacent part.

Dr. Walter Rosenhain, F.R.S., found himself in agreement with a great deal of what the author said, though he thought the idea that a weld could ever be perfect was probably not as illusory as the Paper would lead them to believe. The difficulty, of course, was that it was never known when a weld was only slightly imperfect or very bad. With regard to internal welds, he had recently had an opportunity of examining some cavities in steel, and although they looked perfectly bright, there could be no question that they were not clean metal surfaces. With regard to the other question of whether a segregate, i.e., a non-metallic material lying on the surface of the steel, hindered or did not hinder welding, he could not help feeling sure that if it was impossible to press metal to metal a weld was not obtained. That was known perfectly well from the blacksmith's experience. A blacksmith put a fusible slag on the surface of the welding metal and squeezed it out. In the interior of a blowhole there was no possibility of squeezing it out; and consequently there must be a mechanical difficulty in getting a perfect weld under such conditions. What was commonly called a slag enclosure might be obtained, which was a non-metal enclosure remaining behind, but that could hardly be regarded as assisting the closing up of the blowholes. He thought it would gradually come to be recognised that, if he might use such an expression, the only sound steel was sound steel. The author had made a great advance in the method of detecting the perfection or otherwise of welds, but before feeling quite satisfied with the figures quoted in the Paper he (the speaker) would like to remind the author of the fact that the Izod impact figures were very variable, even in perfectly good material free from all welds and similar features. The author based his estimation of the weldability of a steel on certain Izod impact figures, and quoted apparently single figures. He (the speaker) desired to warn anyone reading the Paper, and trying to employ the method suggested, against being content with anything less than a very large number of Izod figures upon which to base such a comparison, otherwise he might very easily be misled as to the relative weldability of two kinds of steel. Finally, he did not think quite such a debt of gratitude was owing to sulphur in steel as the author would have them believe. He would remind the author that it was possible to find out quite a lot about the past history of steel from its microstructure obtained from etching with any of the cupric re-agents or certain other well-known means, and even if there was no sulphur, and even if the phosphorus was very low, it was still possible to obtain all the information desired, although not, perhaps, quite so easily as with a sulphur print. He thought any metallurgist who read the sulphur print as indicating merely a presence of sulphur and nothing else was neglecting nine-tenths of the valuable information it conveyed. It could be regarded as a valuable guide to the various things that were present in the steel associated with the sulphur, although not necessarily as cause and effect. The Paper put the whole question of the character of welds on a sounder basis than before, although the welds themselves were apparently not as sound as earlier workers would have them believe.

Dr. L. Aitchison said the author would render a very important service if he could show a reasonable method of determining whether the unsoundness of nickel-chromium steels was more harmful than the corresponding unsoundness of carbon steels. He had turned to the figures given in the Paper with a considerable amount of interest, because he wanted to find out that particular information which the author rather suggested he could give. He felt, however, some disappointment when he looked at the figures given for steels "A," "B," "C" and "D." Even allowing for the fact, as Dr. Rosenhain had suggested, that they were based on a number of observations, he did not think they led to a very sound conclusion. He would like the author's confirmation that they led to the conclusion that a plain carbon steel welded up better, by test, than a nickel-chromium steel. The figures upon which the weldability of the material was judged were ordinary Izod impact test results. They were not an absolute physical quantity, and were only very relative. When impact test results were being evaluated they must be taken in conjunction with the tensile strength of the steel upon which the test was obtained. The author had not quoted the tensile test results, but he (Dr. Aitchison) estimated from the composition of the steels, the size of the bar, and the heat treatment, that steel "A" at the critical welding figure had a tensile strength of 45 tons; steel "B" a tensile strength of 75 tons; steel "C" a tensile strength of 85 tons, and steel "D" a tensile strength of 90 tons. The tensile strength and the impact figures, therefore, ran

together and gave exactly what would be expected. He suggested that the real evidence of the welding figures was that all the steels welded to the same degree, and that steel "A" did not weld twice as well as steel "D." Impact figures could only be interpreted in relation to tensile strength; in his opinion the impact figures and tensile strength went together and showed absolute similarity. The author's method of dealing with the influence of sulphur was very interesting. He had suggested a method of finding out whether the actual proportion of sulphur in a material had any effect upon the way in which the segregated areas would become what was called sound. It was understood that sulphur would segregate in all ingots, and there was likely to be a higher proportion of sulphur in some form or other in the centre than along the edge. If a series of ingots containing different proportions of sulphur were made and rolled down there would be in each case a different proportion of sulphur in the middle and the outside, and it was possible to test by the author's method whether a high-sulphur steel gave a worse ratio between the centre and the outside than a low-sulphur steel. He happened to be able to give the members some test results which had been obtained upon a series of ingots containing sulphur in the following amounts: 0.062, 0.09, 0.1; 0.13, and 0.17 per cent., and they showed that the variation in the percentage of sulphur did not in any way influence the ratio between the impact value on the outside and the centre. Therefore if the author's method did indicate the weldability of the material, his method also showed by that experiment that the actual quantity of sulphur had no effect upon the way in which the material would weld up.

Mr. J. H. Whiteley, referring to the author's previous Paper on the same subject at Middlesbrough, recalled that in the discussion on that Paper he (Mr. Whiteley) had expressed the opinion that the author was not justified in drawing the conclusions he had done in regard to the non-weldability of blowholes in steel from the experiments he had made, because in all the experiments the author had carried out the welds had been made in air, and air was certainly not present in steel blowholes. It was well known that when ingots were cut the blowholes were nearly always bright and untarnished, and although they might sometimes contain sulphides and silicates no oxide was present. He thought it might be assumed that no matter what the composition of the gases the equilibrium composition shifted with the increasing temperature. In the presence of carbon in the steel and hydrogen in the blowholes the character of the gases would always remain reducing in regard to the formation of iron oxide. Therefore when the two surfaces met they should weld perfectly, because there was nothing to hinder it. He supported that statement by describing some experiments he had made in which he had welded small bars of pure electrolytic iron in dry hydrogen and also in air. On sectioning the welds for the microscope, he could find no traces of the junction of the welds in the hydrogen case, but in the air welds the junctions were plainly visible, and, moreover, on applying a severe crushing test to the steel the hydrogen weld stood it perfectly, no cracks appearing. In the case of the air welds, however, the steel tended to split apart along the weld junctions. He gathered from the author's reply to the discussion at Middlesbrough that he was not satisfied with the tests which he (Mr. Whiteley) had made, and he therefore determined to repeat the experiment, and on that occasion to apply the author's own test to the welds. He therefore obtained a bar of mild steel containing 0.24 per cent. of carbon and the usual amounts of the other constituents, and bored it down at one end to form a tube, which was closed at the other end. He then inserted a plug of the same steel, about 2-in. long, the plug being split in two longitudinally so that there were three welds altogether. That plug in the steel he then welded in dry hydrogen. He also welded in air another plug of the same steel in a small tube, also of the same steel, about 4-in. long, *i.e.*, he simply plugged the end up with a small plug of the steel. He did not fuse it, as the author had done; he simply plugged it up, so that the weld remained in air. He then forged a bar of the steel down to ½-in. square, so that he had three pieces altogether—a bar ½-in. square welded in hydrogen, a bar welded in air, and the original piece. He then quenched them in oil, as the author had done, at 900 deg. C., and tempered them at 550 deg. C. or 570 deg. C., and impact tests were very kindly taken for him by the chief chemist of Messrs. Bolckow, Vaughan & Company. The results of the impact tests, two in each case, were as follows: The original unwelded bar gave 97 ft.-lbs. and 95 ft.-lbs.; the bar welded in hydrogen 107 ft.-lbs. and 103 ft.-lbs.; and the air-welded gave 110 ft.-lbs. and 113 ft.-lbs. There was no difference in the fractures between the hydrogen-welded and the normal bar. The welds did not strip, but in the case of the air weld traces of the welds could be seen in the fractures, as the author had shown. Under the microscope he could find no trace of the weld in the case of the hydrogen weld, but the air weld could be seen. He therefore still held to the opinion that under right conditions steel could be welded perfectly, *i.e.*, it could be made so that it might have been cast without any subsequent treatment. There was one condition of his experiment, however, which did not obtain in the blowhole. During the welding the hydrogen could escape from between the surfaces up the tube. That, however, did not obtain in the blowhole. If the hydrogen was going to escape as the steel was rolled or forged, it must escape through the walls of the steel, otherwise it would remain behind, and if that happened discontinuity would take place. If the hydrogen or the other gases could not escape, then a film, or a compressed layer, or small blowholes of gas would occur, and the steel would not be sound. That, he thought, was the condition which the author had brought about in his experiment, because after inserting his plug he fused over the ends of the cylinder which he used and hermetically sealed the gas. If the author examined his welds very carefully with a high-power microscope he would find evidence of sponginess, which would at once account for the serious stripping he had obtained in his tests.

Dr. W. H. Hatfield, referring to what he described as two essential points raised by the author, (1) whether blowholes, segregates and pipes resulting from segregates would weld up, and (2) the influence of sulphur and phosphorus segregates upon the utility of steel for different purposes, said that with regard to the welding up of cavities and blowholes, there could be no question that the evidence the author had adduced finally and firmly established the fact that if cavities or blowholes were present it was impossible to expect that their effect could be entirely removed. That emphasised the very important point that in manufacturing steel ingots every care must be taken to ensure that they were free from internal defects. That was particularly necessary in the production of alloy steels and steels which were to be used for parts which were to be highly stressed. His firm had practically completely adopted an inverted ingot with a good refractory head. That meant that the pipe was in the top of the ingot, with perhaps just a little segregate below the pipe, but apart from that all the ingot was substantially free from internal defects. Apparently it was necessary, however, owing chiefly to the cost of production, to have a large head for the production of structural steels, and it was impossible, therefore, to scrap from 35 per cent. to 40 per cent. of the top end of the ingot. Ingots were still being produced in the shape he had described, containing a large number of blowholes. As long as the fact was recognised that ingots which contained blowholes did, after rolling or forging, contain a weakness where those blowholes or pipes occurred, that was sufficient for the purpose. Turning to the question of high sulphur and phosphorus, he did not agree with the author that sulphur might be carried as high as was suggested. He thought it was obvious that manganese sulphide was a very brittle non-metallic substance, and that the less there was of it in steel the better. It was quite clear that, as far as commercial consideration would permit, the amount of sulphur and phosphorus present should be as reasonably low as possible, and he therefore deprecated the author's suggestion that for spring steels and steel of that class ingots might be used which were high in impurities.

Sir William H. Ellis, G.B.E., did not think a discussion on the Paper would be complete without going back to a subject which at one time interested the Institute very much, namely, that of compressed ingots. Those ingots were largely used for big work, and so far as he knew their use was continued. Some years ago, when he was using a large number of those ingots, he found on cutting them up that uniform and definite conditions existed in the head, and that caused him to make certain experiments on the question of welding. They appeared to him to be conclusive on one point, namely, that if there was a vacuum—or, to speak more scientifically, an absence of access for oxygen—perfect welding, so far as one could use that expression, was possible.

Dr. A. McWilliam described it as curious that the very ancient process with which the Paper dealt should still require clearing up, but it was certainly the case that it was not yet thoroughly understood. He remembered many years ago, when he had absolute confidence that welds were perfect, being very much surprised by a manufacturer showing him how they could be torn apart even when the two materials seemed to have joined together thoroughly as examined under the microscope. One good point in connection with the question of the gases that existed in blowholes was that if an ingot was made with the right number of blowholes in it there would be a reducing atmosphere within the small cavities, whereas with what was sometimes called a "cauliflower" top it would draw oxygen from the air and become oxydised. Manufacturers had been criticised recently for discussing such questions, which had the effect, like the fat boy in "Pickwick," of making the flesh of their

customers creep, but notwithstanding all the dreadful things to which reference was made the steel still seemed to serve its purpose. One responsibility he had to sustain in connection with the method of selection of the type of ingot to be made was not particularly to pass any judgment from a microscopic point of view, but to see that the materials stood an exceedingly severe shock test of the more ancient form. Those materials were tried first of all in sample heats, and put through tests very much more severe than those that they were required to stand when in use, and they stood them successfully. One point to bear in mind was that they must not get super-sensitive in connection with a number of the questions that had been dealt with; all they had to see was whether the steel was doing the job for which it was made. With regard to the question of gas, he confessed that although he did not know what happened to the gas he used to teach that it was highly probable that it would be re-absorbed, a statement with which he thought Dr. Arnold would agree. They used to consider in the old days that the gas would probably be re-absorbed in connection with the working up of the steel.

COLONEL CARNEGIE said the Paper had recalled to his memory a very serious trouble in connection with the ingots made for shells during the war, a trouble largely due to the fact that they were not at the time conversant with the best form of ingot to use for punching shells into shape. As a result manufacturers were constantly in trouble. He was referring, not to ingots with blowholes, but to the Canadian experience during the war in connection with ingots which when fractured longitudinally showed a furriness. They were really more contraction troubles than blowhole troubles. In order to save good steel from being rejected several experiments were made. The steel showed contraction areas of the appearance of a segregate, but they were not really segregated. Some of the material was drilled to different depths and punched in the ordinary way, and invariably a button was found at the bottom of the cavity, showing that the metal did not weld up when the holes were drilled, and when the ingot, being heated in the furnace, was allowed to take the oxidation that the furnace gave. When, however, smaller ingots were drilled and plugged, no trace of the plugging was found. They were therefore clearly satisfied that a suitable weld was made. Further, when cross-sectional test-pieces were taken at the bottom of the ingot the same physical properties were found in the material.

MR. COSMO JOHNS said he had two mild complaints to make. In the first place, the author had not given a summary of the conclusions on which he laid most stress, which was the general custom with the authors who read Papers before the Institute. The Paper was a very valuable one, covering a very wide range of subjects, and it was difficult to appreciate the points upon which the author laid most stress unless a summary were given. His second complaint was that he was afraid several of the members who had preceded him in the discussion had referred to subjects quite different from those dealt with in the Paper. Steels which contained cavities formed from different gases might be divided into three classes: (1) Dead mild steels, viz., those used for sheet bars and plate bars. (2) Steel in which blowholes were always left which welded up or closed up. Except in special cases where blisters occurred due to improper casting or melting a steel, that steel was from the practical standpoint good. It was entirely different in composition from the steels in the other two classes. In high-tensile carbon steel it had been found from experience that it was not desirable to have blowholes; there must be a sound ingot, and if it was not possible to cast the ingots in the best possible form when making high-tensile steels, only the lower or sounder portion of the ingot should be used for the high-tensile steel, and the other portion for something less important. (3) The third class consisted of the alloy steels, special steels which were treated differently and used for different purposes. They were stressed transversely, and it was the transverse tests that had to be provided for, because they were the only ones used. No dogmatic assertion made as to the reliability of welds could apply to all steels. As a matter of fact, the so-called perfect ingot of the inverted shape was used to his knowledge at Llandore in making tinplate dead-mild steels, and it was used throughout South Wales at the present time for making mild steels. Theoretically, if two chemically or optically clean surfaces of iron were pressed together at high temperature in the presence of hydrogen or in an absolute vacuum, the two surfaces could be welded no matter what the steel was, but in practice it could never be done. The difficulty in practice was that with hidden cavities one never knew whether there were clean surfaces or not. Alloy steels were tested transversely; the imperfectly united surfaces lay across at right-angles to the test piece and at once showed up. Another important point connected with the subject was the hair-lines. He gathered that their friends across the "Herring Pond" must have had serious difficulties with that particular class of defect, because he noticed in the American journals a series of papers asking why such things occurred. It was well known that when it came to a question of making steel to the specification of the British, French, and Russian Governments their American friends found it was a very different proposition to making steels of the very large outputs to which they had been accustomed. The author dismissed the cause of the appearance of those hair-lines by adopting one of the several theories that had been put forward, namely, that they were due to fissures. He thought it would be very useful if the subject could be taken up and discussed, because at the root of it lay those principles which Professor Arnold thought should be discussed in preference to details. No theory had as yet been accepted as to why blowholes should be produced and why non-metallic substances should occur in steel, and until some theory had been accepted it was difficult, as Dr. Arnold said, to discuss the Paper. Personally, he had quite a different explanation to offer as to why the hair-lines occurred, but it was clear that in practice welding could not be effected by rolling.

MR. E. H. SANITER thought there had been a good deal of loose talk on the part of many who had discussed the Paper. Nearly every speaker had accused the author of saying that a blowhole would not weld up. As a matter of fact, the author said nothing of the sort; what he said was that a blowhole would not weld up perfectly, which was a very different thing. Was there anything that would weld perfectly. Some people talked of a weld from the point of view that it should be as perfect as a steel which had never had a weld in it. If a piece of wrought iron were treated in the same way that steel was treated it would break down under the impact test, showing that a weld in wrought iron, which was supposed to be the best welding material, was just as imperfect as a weld in steel. It might be the case that under special conditions a weld could be made that could not be torn apart. He was not at all sure on that point, but he was sure that if those special conditions did not exist, any weld could be torn apart, whether it was wrought iron or steel specially prepared for welding, or whether it was a "blowhole" steel. In his opinion the Paper was more a paper on sound steel than on welding, and its real point was that the author advocated a steel being made which contained no blowholes, nor, as far as possible, any other things which would prevent continuity in the metal. If that could be done every time, practice would be improved. At the same time, there were certain articles and trades in regard to which it was almost impossible to prepare a steel of that description for the special qualities required. He thought it was necessary to be very careful before any statement was bluntly made about the welding up of blowholes. One qualification which could be made was that blowholes did not weld equal to a material in which there had been no weld, but he did say that they would weld up. Probably 80 per cent. of the steel made in this country had been made of steel with blowholes in it which had been welded up, and which served its purpose with great success.

MR. C. H. RIDSDALE said that the author referred to the difficulty of getting thorough welds if a slag of the right fusibility was not obtained. It was a great pity that more common use was not made of siliceous slags of low fusibility for commercial purposes. It was well known that a great many commercial welds were made with no flux at all, but they ought always to have a flux, and if a siliceous slag of low melting point were used difficulty would not occur through the unequal amounts of slag and oxide of iron. The remarks the author had made in regard to sulphur had been called in question. He thought all the author had been doing was trying to bring about a properly balanced view with regard to the effect of sulphur. As the author said, what might appear as a defect under one set of circumstances became an advantage under another. With regard to the least harmful of the segregates being probably sulphur, it should be borne in mind a little more clearly that, just as during the war aliens were segregated in order to make them relatively harmless, so if there was a segregation of impurities they would become relatively harmless. In various steels there was not only sulphur but phosphorus in what might be called a harmless condition; it was separated out from the mass, and in that state it did very much less harm, provided that the strains did not come in the wrong way for the segregate. With regard to the main point, he quite agreed that it was not possible perfectly to weld a blowhole in ingots or to be perfectly certain that all the blowholes were always welded. When that state of affairs was reached it seemed to him that the mere fact that 70 or 80 per cent. were welded up did not very much matter. The author had pointed out that if there

was imperfect welding a crack going transversely across the mass was often brought to a stop. It was well known that if there was a crack in glass a drilled hole would prevent that crack travelling Therefore, as in wrought iron there was a toughness transversely because of the fibre and the segregate, so there was no need to worry too much about whether or not the blowholes welded up, because if they did not weld up completely there were many more points at which any crack would be arrested in its travers ing. To make a rather bold statement, he had always thought that if it was possible to obtain what the metallurgists called the ideal steel, absolutely sound and dense, it would be much more liable to cracks going right through it, because if once a crack was formed there would be nothing to stop it going right through

Mr. J. C. W. Humfrey, referring to the hair-line cracks in nickel-chrome steels, said he rather gathered that Mr. Brearley thought they were originally ingot defects. He (the speaker) had examined a good many of the fractures, and in no case had he ever found any connection between the line of the crack and the casting structure of the ingot as revealed by macrostructure and etching. In every case the hair-line crack had gone quite at random across the macrostructure. That was rather against the theory of the crack being formed in the ingot. Another point on the question of welding might be of interest. During the war a number of small gun tubes showed cavities near the muzzle. In machining the muzzle of the gun cavities were found up to a size large enough to put one's finger in. The tubes were about 4 in. in diameter and were forged so that the muzzle of the gun, where the cavities were found, came at the bottom of the ingot, and accordingly there was no question of pipes and probably no question of blowholes either. Finally, he was able to obtain a section of one of the ingots, which was found to be perfectly sound all the way down with regard to blowholes and piping, but down the centre there was a series of very fine fissures, which were formed evidently by the final contraction of the ingot as it set—they went straight and parallel to the sides. Near the bottom they turned into a cone. The tubes were forged with an enlarged end in order to get material for transverse test-pieces. Sometimes the end was removed and sometimes a portion left on, and apparently the cavities came somewhere about the junction at the enlarged end. He put the whole thing down to the fact that when the defects were forged in one particular direction there might be a tendency to open them out, and he thought that was what occurred in the present case. The example of the guns was a special case which he thought might have some bearing on the question of welding. The defects existing in the ingot were nothing but the finest of hair-line cracks. With regard to the method of testing for welds by the Izod impact test, he thought the impact test did not give really enough information, as there were many other factors coming into the Izod test which disguised the whole thing. He would suggest to Mr. Brearley to try a slow method of notched-bar testing. In that case any defect which stopped a crack gave a very marked break in the curve. He had actually tested pieces in which in a stress-strain diagram there was a sudden crack with an absolute stop, and then the crack went on again later. It was a very good method in testing small welding defects.

The President said the fact which had arisen out of the discussion was that a weld was only an imperfect method of uniting two surfaces of metal. So far as the differences between other workers and Mr. Brearley were concerned, Mr. Brearley held that the gases in the blowholes, whether they were lined with non-metallic substances or not, were responsible for the imperfect welding of a blowhole. He had gone into that matter very fully long ago, and had come to the conclusion that, where a big ingot was rolled down to a rail or plate, in the places where the honeycombs were lined with sulphides there was a separation, and, even when the sulphides were deposited independent of a blowhole, cross-sections taken from a perfectly sound rail made from a perfectly sound ingot showed sulphur lines when they were subjected to bending or were broken. The discussion clearly showed that more information was required. The great feature of Mr. Brearley's Paper was the suggestion that the matter should be continuously and more fully studied. It was well known that, in order to make "wrought-iron steel," viz., a steel with a very fibrous structure, it had been the practice to add sulphur purposely and then to get a longitudinal fracture very much like the fracture of wrought iron. Brinell tested by the shock test steel to which he had added a large amount of sulphur, and he got the very best tests out of the high-sulphur steels. When the strain was applied at right-angles to the direction of the rolling there was a very different result. It was always necessary to take into consideration, when talking about shock or any other tests, the relation of the stress put on in the test to the direction of the rolling. He congratulated Mr. Brearley upon his Paper, and thought it would inspire more thought and more investigation and that the net result would be a great advance in knowledge with regard to welding. He himself would like some information as to the effect of nickel and chromium and other impurities in steel in connection with welding. He had recently had a good deal of complaint about soft steel not welding, and in one case there was nickel about 0.12 and chromium considerably high, and he was asked why it did not weld. Did chromium and nickel reduce the weldability of steel? It was a very important point, and would have to be considered.

Mr. Brearley indicated that he would give his reply to the discussion in writing.

Cupric Etching Effects Produced by Phosphorus and Oxygen in Iron.*

By J. H. Whiteley (Stockton-on-Tees).

The use of cupric reagents by metallographists for etching plain carbon steels, in order to detect structural heterogeneity, has developed to a considerable extent during recent years. Quite a number of these reagents have from time to time been suggested, and while, in certain cases, some may be more suitable than others, there is no doubt that they one and all reveal the same structure when applied to the same specimen. Certain parts are attacked to a greater extent than others, and contrasts are thereby obtained which are intensified by the deposition of a film of copper on the areas most deeply etched. The author's investigation had two main objects in view: (1) to determine whether or not the cupric reagents will detect small variations of the phosphorus content only, synthetically produced in samples of electrolytic iron; (2) to endeavour to produce in iron samples variations of the oxygen content only, which could be detected by the cupric reagents. The author remarks that the investigation must be regarded as chiefly preliminary in character. The method of synthetically producing heterogeneity of structure which has been used is one that appears capable of extension in several directions. Briefly he summarises the two results which have so far been obtained as follows:—

(1) Differences in the phosphorus content of less than 0.02 per cent. in adjacent parts of otherwise pure iron can be readily discovered by means of the cupric reagents; as the difference is increased, at any rate up to 0.15 per cent., the contrast becomes more and more pronounced. These differences were produced by first phosphorising strips of the iron with phosphorus in hydrogen at 1,000 deg. C., and then welding, in hydrogen or other gas, a pile made up of alternate strips of phosphorised and unphosphorised material.

(2) Attempts to produce, in a similar way, an unequal distribution of oxygen, which could be detected by the cupric reagents in the same manner as that of phosphorus, have failed. When oxygen was present, white resist-lines were formed only at the weld junctions, but these resist-lines were not formed when unoxidised iron was welded in dry hydrogen. Two methods of obtaining an unequal oxygen content were used: (*a*) by soaking pure iron in its own oxide at a high temperature and then welding it with the unoxidised material; (*b*) by reducing highly oxidised iron in hydrogen and then welding it with the original metal at a low temperature.

Mr. A. Fletcher, president of the American Locomotive Company; Mr. W. H. Woodin, president of the American Car and Foundry Company; Mr. Estep, of Perrin, Marshall & Company, consulting engineers, New York; Mr. L. B. Parker, of E. L. Soule & Company, iron and steel merchants, San Francisco; and Mr. W. W. Butler, president of the Canadian Car and Foundry Company, are at present visiting this country.

Mr. E. E. Wallington Butt, formerly assistant engineer to the Birmingham Public Works Department, has been commissioned by the United States Government to advise the Navy Department at Washington on airship matters. During the war Mr. Wallington Butt held an important staff appointment at the Admiralty on work with the Royal Naval Air Service, and has since practised as a consultant in London.

* A Summary of a Paper presented to the Spring Meeting of th Iron and Steel Institute.

The Plastic Deformation of Malleable Iron.

The subject, which forms a useful adjunct to the papers which were recently presented to a conference on the failure of metals, was dealt with by Mr. H. A. Schwartz in a recent issue of the "Iron Trade Review," of which the following is an abstract:—

The behaviour of malleable cast iron under mechanical stress is that, like most other materials, its deformation, or strain, under load is of two entirely distinct characters, depending upon the intensity of the stress. Under light loads the deformation is elastic; that is, it is proportional to the applied stress and is not permanent, the metal returning to its original dimensions upon the removal of the load. At higher stresses the strain increases very rapidly and the specimen becomes permanently deformed.

This change of form is termed "plastic" deformation as distinguished from "elastic," and especially characterises ductile metals. Much interesting work has been done in the investigation of the phenomenon of plastic flow, the property by virtue of which a material is malleable and ductile. The property is usually measured in terms of yield point, reduction in area and elongation.

The author has no desire, in the present connection, to attempt any exposition of the theoretical

FIG. 1.—INTRA GRANULAR FRACTURE OF A FERRITE GRAIN IN MALLEABLE IRON, THE PATH OF RUPTURE ADVANCED ABOUT TWO-THIRDS THROUGH THE GRAIN AT RIGHT-ANGLES TO THE SLIP BAND (MAGNIFIED 1,000 DIAMETERS).

aspects of plastic flow. However, since malleable cast iron is in quite a marked degree capable of plastic deformation, and in fact owes many of its most valuable properties to this property, it seems well to summarise the effect of plastic deformation on the metal.

Summary of Theory.—Malleable cast iron is in effect a mass of ferrite made up of individual grains. Each grain is made up of many crystals all oriented in space in the same direction. The several grains are held together, according to the now generally accepted view, by a thin layer of amorphous (non-crystalline) iron acting as a cement. This amorphous iron is supposed to be stronger than the crystalline variety, and is supposed to behave like a very viscous liquid. It is also supposed that crystalline iron will go over into amorphous iron under heavy stresses.

The behaviour of a metal under even the simplest stresses is, as a rule, complex. Even when a stress is applied in only one direction the behaviour of the material indicates that complex systems of forces result. Whilst elongation or compression of a metal is spoken of, these terms are in a sense misnomers, since solids are but slightly compressible in the sense of a decrease in volume or *mutatis mutandis* capable of elongation. Metals compressed or lengthened by plastic deformation do not materially gain or lose bulk. For example, a specimen compressed until it was only one-fourth its original height had its density reduced from 7.206 to 7,196 in the process, a change in the opposite direction to what might be expected.

Behaviour of Specimens.—The increase or decrease of dimensions parallel to the direction of applied stress is made up by decreases or increases of cross section in a plane normal to the axis of stress; the tensile specimen necks in the compression specimen becomes barrel shaped.

Plastic materials do not fail in tension or compression in a plane normal to the stress. The tension specimen shows a cup-shaped fracture, at least on one side of the break. The compression specimen tears apart either in a plane approxi-

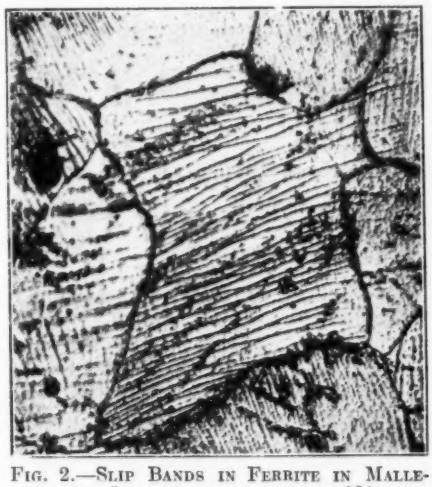


FIG. 2.—SLIP BANDS IN FERRITE IN MALLEABLE IRON (MAGNIFICATION 1,000 DIAMETERS BUT REDUCED IN REPRODUCTION).

mately at 45 deg. to the direction of stress, or more rarely on a conical surface whose axis of symmetry coincides with the direction of load.

From these observations it is evident that there is a considerable motion of translation within the stressed material in directions at right angles to the direction of the applied stress. This rearrangement may conceivably be of two kinds in a material composed of crystalline grains, either a deformation of the individual grain (intragranular) or a separation and rearrangement of the grains at their boundaries (intergranular).

Both phenomena are easily recognised. A deformation of the grain itself is accomplished by a shearing of the grain along the intragranular

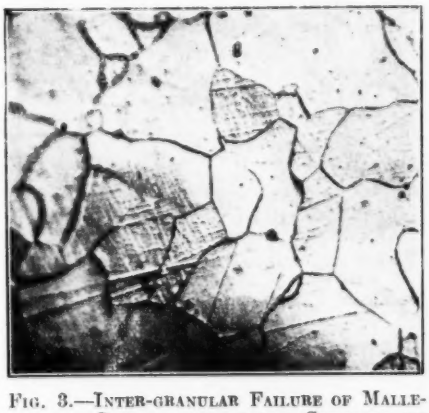


FIG. 3.—INTER-GRANULAR FAILURE OF MALLEABLE IRON IN WHICH THE SURFACES DO NOT APPEAR TO BE IN THE SAME PLANE (MAGNIFIED 400 DIAMETERS BUT REDUCED IN REPRODUCTION).

crystal boundaries. Such a slip, if occurring in a grain in a polished surface, shows a series of parallel lines on the polished surface which are fine grooves and ridges in the originally plane surface.

Fig. 2 shows a micrograph at 1,000 diameters of such slip bands in a ferrite grain in malleable cast iron. Such a deformation, increased in magnitude, may result in the rupture of the grain itself

at right angles to the slip bands, as shown in Fig. 1, or by producing such a distortion of the grains that it can no longer articulate with the surrounding grains closely enough to be held to them by the cement of amorphous iron at the boundaries.

Change of Structure when Deformed.—On the other hand, examination of the originally polished plane surface of a specimen parallel to the direction of stress which had failed by primary intergranular fracture would show no slip bands, but a considerable displacement of the polished surfaces of the individual grains from their initial location in the polished plane provided the failure was due to shear at the grain boundaries. On the other hand, if failure was due to forces having a tensile component normal to the grain boundary, the

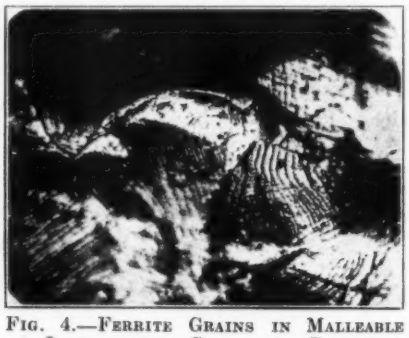


Fig. 4.—Ferrite Grains in Malleable Iron, showing Slip in two Planes at Right-angles. The Cohesion at the Grain Boundaries is still strong, even after severe Plastic Deformation.

separation of originally adjacent grains would be shown.

Where the conditions have been such as to produce fairly great plastic deformation it may even be possible to note the effect of intragranular flow in the changed orientation of the polygous marking the individual grains.

In unworked ductile metal there is no preference as to the direction of the longer diameters of the grains in any given surface, nor are the diameters in various directions widely different. After plastic deformation however the originally equiaxed grains may be flattened into sheets, drawn out into threads, etc., depending upon the character of the stress and the direction of the

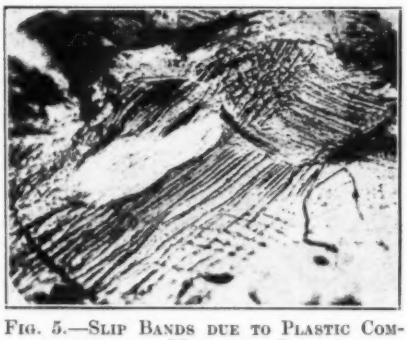


Fig. 5.—Slip Bands due to Plastic Compression in Malleable Iron (magnified 500 diameters but reduced on reproduction).

stress with reference to the polished surface under examination. Obviously such changes of form can be detected best in a plane paralled to the direction of load, and are visible only as changes of grain size in a plane normal to the deforming stress.

Microscopic examination of the path of rupture through a metal, of the deformation of grains under load or, when applied to surfaces prepared before the application of the stresses, of intragranular slip and intergranular displacement is capable of interesting disclosures as to the mechanism of plastic deformation or ultimate failures under various types of stress.

A summary of the changes in malleable is attempted in the accompanying photomicrographs. Fig. 3 shows an unusual failure of intergranular type. It will be seen that at several points the grains have the appearance of being above or below the general surface. These grains have slipped not on the crystal faces within the grains, but at the surface of contact of adjacent grains. The field of view is near the compression side of a piece distorted by cross bending, and it is possible that this slip at grain boundaries produces the white so called compression fracture. The comparative absence of slip bands is interesting.

Fig. 4 is reproduced from the tension side of the

Fig. 6.—Plastic Deformation of Malleable Iron in Compression resulting in the Distortion of Temper Carbon (magnified 100 diameters but reduced on reproduction).

same piece, and shows well developed bands. In some grains two systems of bands are seen due to slip along two directions. The fact that the adjacent grains are not separated even under heavy strain shows the strength and ductility of the amorphous boundary.

Fig. 5, taken from a piece loaded in pure compression, shows that the structure of Fig. 3 is not

Fig. 7.—The same Specimen as Fig. 6, but is near the Surface, whereas Fig. 6 is near the Axis.

always characteristic of this type of loading, and also shows plainly two systems of slip bands in practically every grain. In all of these photomicrographs, note that the direction of slip is constant in any given grain, but is not usually the same in adjacent grains. The direction of slip has no direct relation to the direction of the stress, but is determined by the direction of the

crystallographic axis of the ultra microscopic crystals making up the individual grains.

Figs. 6 and 7 show the distortion of grains in compression as seen on a polished section parallel to the direction of stress prepared after the distortion has occurred. The grains are much flattened, as are the nodules of temper carbon. The grain boundaries are nearly obliterated, but there is no separation of the adjacent grains. The effect is more strongly marked at the axis of the specimen than near the surface, due to the fact that the barrelling out of the specimen has permitted part of the reduction in height to be made by bending the outer fibres instead of upsetting them. The specimen from which these illustrations were made was compressed to a little less than one-half its original height.

Fig. 8 shows the path of rupture of malleable broken in cross bending. It was prepared by breaking a wedge-shaped piece by bending it over until fracture occurred. The fracture was then

FIG. 8.—PATH OF CROSS BENCHING RUPTURE THROUGH MALLEABLE (MAGNIFIED 200 DIAMETERS BUT REDUCED ON REPRODUCTION).

plated with copper, the specimen sawn in two at right angles to the ruptured surface and parallel to the cross bending stress and the exposed surface polished.

It is particularly interesting to note how the path of rupture goes far out of its way to include temper carbon nodules. This makes many deep depressions in the broken surface, and due to the shadows in the bottom of these depressions produces the characteristic black fracture of the product. It is not often recognised that the presence of temper carbon is not a sufficient explanation of the black fracture, for this material, representing about 6 per cent. of an average cross section, would not be nearly sufficient to darken the surrounding silver white metal.

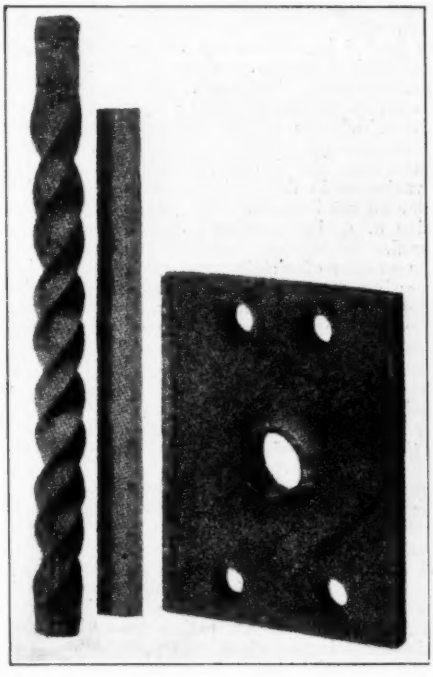
It is only due to the fact that the plane of rupture takes in many more nodules of carbon than would be found in an average section, and in doing so produces a sort of " nap " that the fracture appears as dark as it does. A fracture running at random along the grain boundaries would be steely and crystalline in character.

SUSPENDED MOULDING MACHINE IMPROVED.—The Howe-Teetor suspended moulding machine, manufactured by the R. J. Teetor Company, of the U.S.A., has been considerably improved by the addition of a number of new features. The improvements include a swinging riddle shelf. The riddle slides on an angle frame which swings on the supporting column of the machine and permits the moulder to shake down the sand by merely pushing the riddle back and forth. As the shelf is pivoted on the column it may be pushed to one side when not in use. Another new feature lies in the provision made for lifting the legs of the machine to the level of the bottom of the body, thus permitting movement of the machine over completed moulds on the floor. This feature is said to be of particular convenience in malleable foundries where heats are taken off at various times from different furnaces. A mechanism for reversing the machine can be supplied when desired, although regularly the machine is furnished with a rigid overhead trolley. The machine can be equipped with either a plain bench or a standard air squeezer, and changing from one to the other is easily effected.

Tests of Malleable Castings.

The American Malleable Castings Association made some interesting tests of the physical properties of malleable iron castings at the National Railway Appliance Association exhibition held recently in Chicago. A working demonstration was shown of punching $\frac{3}{4}$-in. holes in 6 × 8 in. malleable iron plates, $\frac{5}{8}$-in. in thickness.

The photograph shows one of these plates punched, the centre hole after punching being drifted to $1\frac{1}{2}$ in. in diameter without reducing any fracture. In some of the 6 × 8 in. plates 20 $\frac{3}{4}$-in.



HOLES $\frac{3}{4}$ IN. DIAMETER WERE PUNCHED IN A $\frac{5}{8}$-IN. MALLEABLE IRON PLATE AND ONE HOLE DRIFTED TO $1\frac{1}{2}$ IN. IN DIAMETER. THE MALLEABLE CAST-BAR 1 × $\frac{3}{4}$ IN. IN CROSS SECTION WAS TWISTED $2\frac{1}{4}$ TIMES WITHOUT BREAKING.

holes were punched, leaving only $\frac{1}{4}$ in. space between the holes, and no fracture appeared in the narrow strips of metal between the holes.

A demonstration was also made of the resistance of malleable castings to strains. Rectangular test bars 1 × $\frac{3}{4}$ in. in cross sections and 14 in. long were twisted on a torsion machine through 800 deg., or approximately $2\frac{1}{4}$ times around without a fracture. Another similar test bar showed its resistance to repeated strains by being twisted 180 deg. three times, being straightened after each twisting. It was then twisted until it broke, the fracture occurring at the end of the complete turn, or 360 deg.

EXPORT CREDITS.—The following return showing the advances made, applications sanctioned, and advances repaid under the Overseas Trade (Credits and Insurance) Act, 1920, has recently been published by the Board of Trade. This report shows that the advances actually made are from January 1 to March 31, 1921, £321,058, the total from September, 1919, to March 31, 1921, is £458,843, and the applications sanctioned January 1 to March 31, 1921, amount to £686,712, the total from September, 1919, to March 31, 1921, being £2,086,746. Up to March 31, 1921, the advances repaid amount to £16,173. These advances have been made to promote trade with Finland, Baltic Provinces, Poland, Czecho-Slovakia, Yugo-Slovakia, Rumania, Bulgaria and Austria.

XUM

The Casting of Metals.*

By Thos. Turner, A.R.S.M.

Speaking generally, all metals have to be melted and cast before they are used. It is true that gold, silver, copper, and platinum occur in the free or "native" state. Iron is sometimes found in the free state, as a result of forest or subterranean fires, and wrought iron is prepared from the ore without previous fusion. But, apart from special cases of this kind, all metals are melted and cast before they are available for use, either as ornament or by the engineer.

The casting of metals, and more particularly of bronze, silver, and gold, dates back to a very early period in the history of the human race. During thirty centuries every great nation has produced statuary in bronze. On the whole, there is reason to believe there are no castings of antiquity which for quality of material cannot be equalled to-day; while it can with certainty be claimed that the size of castings has increased, the variation in design has extended, output has become almost immeasurably greater, and the proportion of spoiled castings, or wasters, has been reduced.

The process of melting and casting metal is an interesting, or perhaps more properly a fascinating, operation. Unfortunately, constant familiarity and routine blunts the finer perceptions, so that the worker in fluid metals may become quite oblivious to the charms of his material, as the sailor or the farmer may fail to observe the beauties of the scenes among which they spend their lives. There is just that spice of danger, and that element of uncertainty, in foundry work which gives a perpetual interest. Unless this keenness can be maintained the best work can never be produced, and the daily task becomes monotonous toil.

Casting Difficulties.—Metal casting may be defined as the art of filling a given space by means of a molten metal or alloy. This may appear to be a very simple operation, yet experience shows that it is the exception rather than the rule to obtain a casting which is really perfect. Among the pitfalls which beset the metal caster A. J. G. Smout mentions furnace treatment, rate of melting, "soaking" and burning, skimming before pouring, rate of pouring, character, cleanliness, and temperature of moulds, and unsuitable or excessive mould dressings. This list is by no means complete. Speaking broadly, the higher the temperature at which the operation has to be performed, the greater are the difficulties which have to be met. Hence a man who has been trained in iron-founding will readily learn to deal with aluminium, while one who has only had experience with aluminium would find that he has much to learn in order to deal with cast iron. Yet the losses in aluminium foundry practice are by no means inconsiderable. The special difficulties which occur in the casting of aluminium are due to a pastiness resulting from oxidation, high specific heat, and high coefficient of thermal expansion; but still, on the whole, it is a relatively easy metal to treat. With metals which have a high melting point, the refractories for furnaces, sand, and cores, nature of the slag, influence of the fuel, change of composition during melting, and other factors play their respective parts.

Small traces of impurity may have a profound importance in connection with metal which has to be subsequently worked. E. J. Young has pointed out it is usually admitted that, with castings, good foundry practice is much more important than slight variations in chemical composition or physical properties, and is much more a guarantee of satisfactory character. Speaking generally, with good foundry practice sound castings can be obtained from any metal or mixtures of metals, provided there are no reactions which lead to the formation and evolution of gases, and that there is no excessive tendency to segregations during solidification.

Fluidity and Viscosity.—Metals were formerly classified into fusible and infusible; with the means now at our disposal all metals can be melted. But in order to obtain a sharp impression of the moulds, and to fill up all parts of a casting, it is necessary not merely that the metal should become fluid when heated, but also that the molten metal should flow freely and quickly into every part of the mould. Pure substances, such as metals, generally melt at a definite temperature, and pass sharply from the solid to the liquid state. Mixtures, on the other hand, may melt over a range of temperature and pass through a semi-fluid stage, during which the viscosity may be considerable. Thus Doetler recorded very high viscosity when dealing with fluid silicates, but C. E. Fawsitt found a very low viscosity when examining a number of pure salts at about 20 deg. above their fusing points. One interesting conclusion of Fawsitt is that the viscosity of eutectic mixtures is greater than that of their constituents. Both Fawsitt and Arpi have studied the viscosity of metals, and the conclusion arrived at is that the viscosity values are much lower than had been expected. Thus the viscosity of certain common metals is as follows: Mercury at 65 deg. is 0.0138; bismuth at 360 deg., 0.0167; tin at 267 deg., 0.0235; and lead at 347 deg., 0.0293. The viscosity of copper and zinc are also low, though Fawsitt did not feel justified in giving an exact value. As the viscosities are in all cases only a small multiple of that of water, it follows that for practical purposes there is no very great difference between the rates of flow of equal weights of water and of fluid metal.

Surface Tension.—There is one important property of the metals as a class that is so general as to be accepted without comment, and yet upon this property successful casting is dependent. If into a prepared sand mould water were poured, the sand would be wetted and the mould spoiled. But when molten metals are poured into a cavity in sand the sand is not wetted, and when the metal has solidified any adhering sand can be readily detached. Why a particular liquid wets a solid, while other liquids do not, is at present not fully explained. The difference is due to the operation of molecular forces, whose effects are seen in cohesion and in surface tension of the liquid. The properties of the solid have also to be considered. The surface tension of metals has been dealt with historically, theoretically, and experimentally by S. W. Smith, who shows that the influence of temperature upon the surface tension of molten metals is small. The values obtained by him for the surface tension of ten common metals in the liquid state are shown in Table I.:—

TABLE I.—*The Surface Tension of Metals.*

	Dynes per cm.		Dynes per cm
Antimony	274	Aluminium	520
Bismuth	346	Zinc	707
Lead	424	Silver	858
Mercury	447	Gold	1018
Tin	480	Copper	1178

For comparison it may be mentioned that the surface tension of water at 15 deg. C. is 73.5 dynes per cm., that of carbon bisulphide about 34, and benzene 29 (Ramsay).

From the internal pressures of solid iron and nickel it is probable that the surface tension of these metals in the liquid state is in the neighbourhood of 1,200. The hardness, cohesion, and surface tension of a metal are functions of the atomic volume. It is to the two latter properties, cohesion and surface tension, that we owe the fact that fluid metal does not wet the mould. If metals did wet the mould, casting, as we know it, would be impracticable. Since metals, at casting temperatures, are far removed from their boiling points, their surface tension is very slightly altered by ordinary variations of temperature.

There is a special surface effect noted with some metals which is a source of trouble in casting. If the metal oxidises and forms an infusible oxide, a skin is produced which may be sufficiently strong to prevent the flow of the metal into the sharp angles or thinner parts of the mould. This is particularly met with when casting aluminium and aluminium alloys, and it is one of the causes

* Extracted from the May Lecture delivered before the Institute of Metals on May 4.

which has prevented any extensive use of aluminium as a softener in iron-founding.

Attention may be called to a simple method of obtaining an approximate determination of the surface tension of a metal, at a temperature near to its freezing point, which may be of interest to those engaged in casting metals. The metal or alloy to be tested is melted and poured out on to a flat slab so as to obtain a plate of approximately circular shape. The thickness of the plate increases with the surface tension of the metal in accordance with the following equation:—

$$T = gd\frac{h^2}{4},$$

where T is the surface tension in dynes per cm., g is 981 (the gravitational acceleration in cm. ÷ sec.^{2}), d the density of the metal, and h the thickness of the plate. It is assumed that the metal does not wet the slab, otherwise it is necessary to introduce a correction in the value of h.

Allowance could be introduced for contraction during cooling, and the slab could be heated to the melting point of the metal to be tested in order to ensure greater accuracy if desired.

It is remarkable into how many problems in metallurgy the property of surface tension enters. Thus it is not only important in connection with casting operations, but it plays a part in determining the melting point of small crystalline granules and in producing the hardness caused by the cold-working of metals. Its influence is also very great in the flotation processes for the separation of metallic minerals, as has been recently shown by H. L. Sulman.

Latent Heat of Fusion.—Provided that other conditions are kept constant, the time required for the solidification of a metal will vary with the latent heat of fusion, or the heat absorbed in passing from the solid to the liquid state. In Table II. it will be observed that there is a striking difference between the latent heat of aluminium and that of other fusible metals. The values given are from determinations by F. Wüst.

TABLE II.—*The Latent Heat of Fusion.*

In Calories per Gramme.

Lead	5.47	Manganese ..	36.65
Bismuth ..	10.23	Antimony ..	38.86
Cadmium ..	10.81	Copper	40.97
Tin	13.79	Iron	49.35
Gold	15.87	Nickel	56.08
Zinc	23.01	Cobalt	58.22
Silver	26 02	Aluminium ..	93.96

Thermal Expansion.—It is well known that the coefficient of thermal expansion of the metals as a class, is greater than that of non-metals. The metals, however, vary considerably among themselves, the coefficient of low-melting-point metals usually being greater than that of those which are less fusible. Hence glass and platinum have very nearly the same coefficient, and the applications of this fact are familiar to the chemist or physicist. Certain metals, whose metallic properties are less pronounced, like antimony or arsenic, have a low coefficient, and also a relatively low melting point. For the purposes of casting, aluminium and antimony afford an interesting contrast. Though their melting points are near together, being 658 deg. and 630 deg. C. respectively, the coefficients of thermal expansion are as 231 to 105. Hence castings in aluminium contract more than those in antimony, and this leads to one of the troubles of the aluminium foundry. If a casting contains a core the metal in cooling tends to bind on to the core, and as the tenacity of the casting is relatively low, even when cold, and is lessened when hot, it follows that there is a great tendency to breakages unless the core is removed at a proper stage in the cooling process. The obtaining of good castings in aluminium thus depends on the recognition of three factors: (1) The high contraction of the metal on cooling; (2) the stage of plasticity between the liquid and the solid state; (3) the low tenacity at high temperatures.

With pure metals the rate of contraction from the hot liquid to the cold solid is usually regular, though not strictly linear, and there is a sharp contraction at the moment of solidification. In special cases, as with iron, an arrest in the rate of cooling occurs, due to allotropic change. Such changes are of the highest possible interest to the physicist and theoretical metallurgist, but do not appear to affect ordinary foundry operations. Impure metals and alloys, on the other hand, often show marked irregularities in their rate of contraction during cooling, and some of these changes have an important influence on the design and treatment of castings. Alloys usually contract less than the mean contraction of their constituents; eutectics usually show a low contraction; while the net alteration in length of a casting, as compared with the size of the mould, depends, *inter alia*, upon the thickness of the metal. The term "shrinkage" was applied by the late W. J. Keep to the difference between the length of a cold casting and the length of the mould into which it was poured. The contraction of the liquid metal on cooling to the point of solidification, and the subsequent contraction or shrinkage in the solid, or partially solid, material may be conveniently studied under two separate heads, namely, pure metals, and alloys or mixtures.

Starting with a pure metal in the liquid state, as it cools it contracts regularly until it begins to solidify. There is a well-known exception in the case of bismuth, which behaves like water, in that the liquid has a point of maximum density, after which it regularly expands, and expands sharply again on becoming solid, after which it regularly contracts. Cast iron, which is a mixture, also expands when cast. But it differs from a pure material, such as bismuth or water, in that the greater part of the expansion occurs after the metal has begun to solidify.

There is a temperature gradient during cooling, as a result of which crystallisation begins at the outside, and is completed near, but somewhat above, the centre of the mass. Metals poured from a low temperature, and those with a high coefficient of expansion, will "pipe" more in the ingot. The size and position of that piping is of the greatest possible importance to the founder. The piping is due to a shortage of fluid metal just before, or at the moment when solidification is completed. If there is any constriction between a mass of metal in the casting and the "gate," the metal will solidify in the thinner portion before the thicker part has become solid. Liquid contraction will then go on in the thick part, and as no liquid is available to fill up the intercrystalline spaces, sponginess results. Such sponginess, or "draw," may be regarded merely as a pipe in the wrong place. Ill-formed and irregular in shape it may be, but it is a variety of piping nevertheless.

The remedy is well known to the practical man; the metal must cool from the outside regularly to the gate, and behind every crystal as it forms there must be fluid metal in communication with the gate, so that there may be no interruption in the feeding in of more liquid to fill the spaces resulting from fluid contraction.

Turning for a moment to alloys, J. D. Edwards, in dealing with the mechanism of the solidification of copper-aluminium alloys, observes that with the alloy containing 8 per cent. of copper (known as No. 12 alloy) the first crystals that are formed at 636 deg. C. on cooling are heavier than the liquid from which they separate, and consequently they tend to sink. The crystals which separate, however, have less copper than the liquid. As a result the liquid increases in density faster than the solid. They become equal in density at about 630 deg. C. when approximately 25 per cent. of the liquid is crystallised. Below 630 deg. C. the crystals are lighter than the liquid, and consequently tend to float.

The difference of density between crystals and liquid may be indirectly a cause of porosity in castings. For example, if a large mass of crystals is floating in the liquid, it may form a network which gains considerable rigidity as freezing nears completion. Consequently, when the eutectic solidifies, there is a tendency for it to withdraw downward from the interstices of this network and leave voids between the crystals, unless additional fluid eutectic metal is supplied. Such behaviour tends to reduce the apparent size of the pipe by converting the upper part of the ingot into a porous mass. Microscopic examination has demonstrated the existence of these voids caused by the withdrawal of eutectic, and density determinations combined with chemical analyses have given further proof of their extent. The presence of such voids is prevented in commercial foundry practice by the use of suitably designed gates and risers.

(To be continued.)

The Eyre System of Oil-Burning.

The superior evaporative value of raw petroleum as compared with coal was established by a series of exhaustive experiments made by Admiral Melville, of the U.S. Navy, which showed that the best coal would evaporate 9.31 lbs. of water per 1 lb. of coal, as compared with 14.45 lbs. of water per 1 lb. of oil, and at a temperature 212 deg. Fah. Amongst the well-known advantages of oil fuel are cleanliness, absence of smoke, ease of regulation and labour saving.

The method or manner whereby liquid fuel is supplied to the burners is commonly called the "oil system." Requirements vary according to the type of the installation and the fuel burned, but experience teaches that the designing of an oil system is quite an engineering feat, for the success of the equipment depends upon the oil system. Perfect combustion gives CO_2. The air pressure should be constant, and the fuel should flow to the burner under a constant, steady pressure, no matter whether that pressure be 1 lb. or 20 lbs. to the sq. in. Light oils, which vaporise at about 130 deg. Fah., need not be heated, but heavy oil or tar must be heated sufficiently to reduce the viscosity so that it will flow readily. This is ordinarily done by means of steam coils. Care, however, must be taken not to get the fuel too hot, for if it vaporises it cannot be pumped.

All pipe fittings should be malleable iron. All unions on pipe lines must be either ground joint or flange unions with lead gaskets. Rubber gaskets cannot be used because liquid fuel soon disintegrates the rubber. The use of a paste of litharge and glycerine on all pipe joints will prevent their leaking. It is essential to place a strainer made of wire netting in the oil tank to prevent lamp-black or other foreign substances from getting into the pipes and valves and clogging them.

According to the manufacturers of the Eyre system, shown in Fig. 1., which embodies the Hoveler burner, the following special advantages are shown: (1) It ignites any given quantity of liquid fuel passing through it in a given time, and in such a manner that all of it is turned into available heat on leaving the apparatus, without smoke and without any loss or waste whatever; (2) the heat generated is also such that it can be applied without any further contrivances or structural arrangements to any coal or coke fire-box in boilers, furnaces, stoves, etc.; (3) it enables the operator to increase or decrease the fire at will, and to keep it either oxidising, reducing, or neutral in such a manner that the temperature and the character of the fire is under absolute control; (4) there are no complicated devices or any structural alterations required inside the boiler or furnace for the purpose of securing uninterrupted ignition and combustion or preventing smoke or incrustation by unconsumed fuel.

At the works of the Eyre Smelting Company, at Merton Abbey, London, S.W., there are about 10 different fires kept more or less continually in operation. Among them are some which have been working for twelve months and longer, day and night uninterruptedly, the atomisers of which are to-day still as good as new. The only thing which has to be replaced occasionally is the fireclay lining at the end of the gasifier, which can very easily be replaced in a short time.

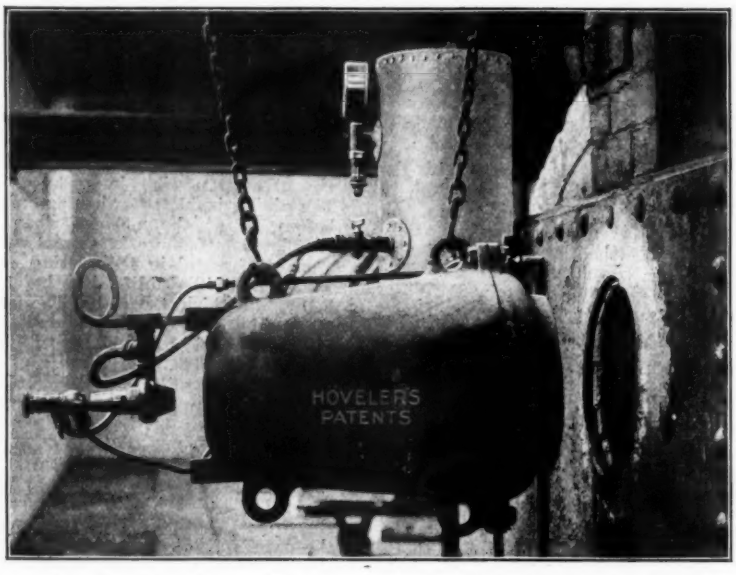


Fig. 1.—Showing the Application of the Eyre Burner.

Use of Gas in Brass Melting.

Mr. A. L. Palmer, in a Paper read before the American Gas Association at their New York conference, gave the following advice to persons thinking of installing gas-fired furnaces. For the gas supply it is necessary to provide piping and meters, to supply without extreme pressure drop, 30 per cent. more gas than it is expected to use, and to carry this pipe full size, with shut-off cock, to within a foot of the burner before reducing to fit the burner connection. When choosing a burner pipe it is advisable to keep down the distance from the fan to the nozzle to 10 ft. Sharp bends should be eliminated from the burner pipe, and whilst straight runs are advocated, it is permissible to use 45-degree bends where necessary. The angle of the nozzle should be such that the flame is midway between the crucible and the furnace wall. If it strikes the crucible directly it will quickly burn out the crucible and lengthen the time of melting. If it impinges or scrubs along the furnace wall near the nozzle it will cause the nozzle to burn away in a few heats.

Further advice was given with reference to the characteristics of the motor corresponding with those of the current supplied, the use of only ball-bearing motors in a foundry, and ventilation by means of a strong natural or artificial draft connection.

Iron and Steel in Sweden.—Published in co-operation with the Jernkontoret by A. B. Svenska Teknologföreningens Förlag, Stockholm, Sweden. This book, though primarily written for buyers of Swedish iron and steel, is of great metallurgical interest, as it describes the work of all the more important ferrous factories in Sweden. The book is well illustrated, and statistics and the history and developments of the works runs into 183 pages One feature, however, is the absence of the names of the British agents, and probably buyers writing direct to the works will be referred back and much time will be lost. It is an omission which should be included in the next edition.

The Climax Cupola.

The portion of a cupola which suffers most under working conditions, and is worn out long before the rest of the cupola, can now be replaced with a new portion, bricked and ready for working in a few hours, by means of the Climax cupola, which has recently been patented and placed upon the market by Messrs. E. Roper & Company, foundry equipment engineers, 71, North Street, Keighley. This is done by making the bottom plate of the wind belt of sufficient strength to carry the cupola and brick lining, and attaching the supporting columns to the under side of this plate as indicated in Fig. 1, which illustrates the cupola in part elevation and part section. The well portion A, that is, the bottom portion of the cupola below the wind belt (in the English type), which carries the hearth and the molten metal held in the furnace before tapping, is made in this design—a detachable portion.

Further, the plate which supports the whole cupola is well away from the heat when the bottom doors are dropped at the end of the blow, and does not therefore become burnt or distorted by the heat. Also, if it is desirable to increase the carrying capacity of molten iron in the cupola well at any time, a new portion of larger capacity can be fitted, making the cupola a more flexible unit.

In the ordinary cupola the well is integral with the rest of the body, the whole cupola being supported on the drop-bottom plate attached to the under side, making it impossible to replace this without dismantling the whole.

In Fig. 2, which shows a further development in cupola practice, B forms the bottom of the cupola proper and C the well or receiver. B is hinged and is independent of C, being supported by a strong hinged clamp; this portion forms bars of a brick grate, with an iron core, which stretches across the middle of the hearth. The core-bar can be readily withdrawn, new grate bricks put into position, and the core-bar replaced, the grate being thus repaired quickly and cheaply.

The well C is provided with a sight-hole, slag and tapping spouts, and has a ganister or permanent hearth; further, it is so mounted on a wheeled carriage that it can be jacked up into position hard against the under side of portion B, or lowered and drawn completely away at the end of the blow.

To start this furnace the hinged part B is put into position and secured, a clay joint being made between this and the under side of the cupola. The bed coke is put in and fired up in the ordinary way, or with a torch through the holes in the brick bottom, the bed coke lighting very quickly owing to the air openings being underneath.

When the coke is well lighted above the tuyeres portion C is put into position, a clay joint being made between C and B. The blast is then put on and the cupola is in operation.

The advantages the patentee claims are as follows:—(1) The metal is carried in the bottom of the cupola but out of contact with the coke, the capacity of the well being also doubled by the exclusion of the coke; (2) the coke bed is reduced to a minimum, which effects a daily saving of coke; (3) all the advantages of a drop-bottom cupola are secured with a permanent bottom or hearth, saving the risk, the sand, and the time of making up the furnace bottom each day; (4) the fettling and patching of the furnace and loose parts are also facilitated, as will be readily seen, and renewals easily effected, as in the previous type described.

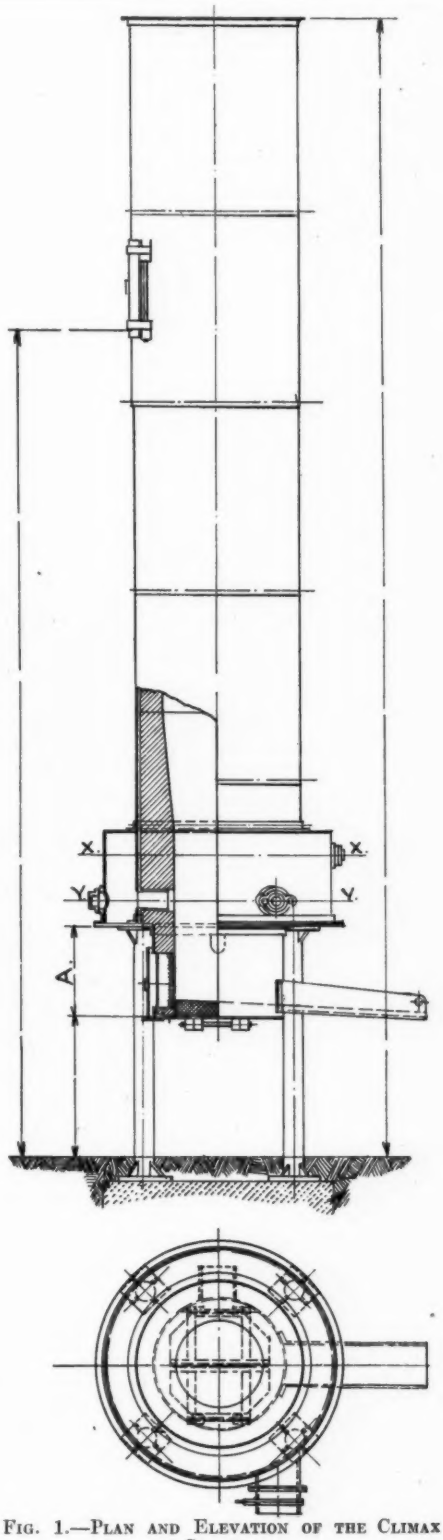


FIG. 1.—PLAN AND ELEVATION OF THE CLIMAX CUPOLA.

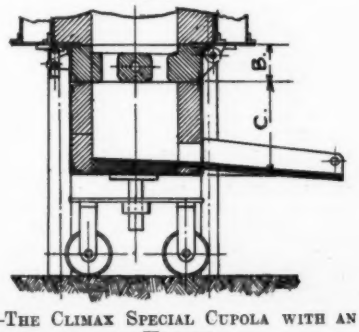


FIG. 2.—THE CLIMAX SPECIAL CUPOLA WITH AN INTERCHANGEABLE HEARTH.

CHILIAN STATE RAILWAYS.—The Administration of the Chilian State Railways is calling for tenders for the supply of tyres, axles and springs to a value of about £75,000. Tenders are to be presented by June 7 next at 10 a.m. A set of plans and specifications (in Spanish) has been forwarded by the Commercial Secretary to His Majesty's Legation at Santiago (Mr. W. F. Vaughan Scott) to the Department of Overseas Trade, 35, Old Queen Street, Westminster, S.W.1, where it may be examined by United Kingdom firms interested, who make personal application at the inquiry room.

Trade Talk.

It is rumoured that an amalgamation is being considered between two independent producers of hematite on the West Coast.

The offices of the Iron and Steel Trades Confederation (No. 5 Division) have been removed to Star Chambers, 144, Commercial Street, Newport, Mon.

The E. W. Harvey Gas Furnace Company, Limited, 10, Queen Anne's Gate, Westminster, S.W.1, have removed to 70, Victoria Street, Westminster, S.W.1.

Two thousand boilermakers at four Jarrow shipyards, as well as painters at one yard, struck last week against the introduction of 15 per cent. reduction in wages.

Returns from the various shipbuilding yards on the Clyde during April show that eight steamers and eleven barges were launched of an aggregate tonnage of 22,956.

With reference to a rumoured order for 30,000 tons of rails for Russia secured by a Belgian sale syndicate, inquiries among the mills in Belgium have failed to elicit any confirmation of the report.

The New Cransley Furnaces, near Kettering, were damped down on Monday. About a hundred men are affected, but it is understood that a number of these will be employed in some way or other.

Palmer's shipyards, Jarrow and Hebburn, are going on four days a week. Night-shift has been stopped at Messrs. Reyrolle's engineering works, Hebburn. A Wear shipyard will also be closed down.

The annual meeting of the Manchester Steam Users' Association was held on the 2nd inst., Mr. Harold Lee presiding. The committee of management reported that 12,541 steam boilers were under the Association's control.

Messrs. Clayton & Shuttleworth, Limited, are reported to have acquired about a one-quarter interest in great engineering works at Vienna and Budapesth, together about three times the size of their Lincoln works.

In Great Britain during March almost 470,000 working days were lost through the existence of trade disputes. The total number of workpeople involved in all the disputes in progress during that month was about 31,000.

The Amalgamated Engineering Union has decided to ask the half-million members to levy themselves for a further 13 weeks at the increased rate of 1s. 6d. weekly for extra assistance to the Society's workless and sick members.

The Industrial Welfare Society is holding a conference of industrial medical men on June 2 at 51, Palace Street, Westminster, S.W.1, when addresses will be given by the recognised experts on the general question of health in factories.

It is officially stated that the United States Steel Corporation have decided to introduce a wage reduction of 20 per cent. Day labourers' pay will be adjusted equitably. This is the first reduction the Corporation has made since January, 1904.

While the returns are not all in, sufficient have been received at the headquarters of the Boilermakers' Society in Newcastle to show there is a majority in favour of resisting the proposed wages cut of 6s. a week for time workers and 15 per cent. for piece workers.

The Viennese geologist, Prof. Edward Suezs, is reported to have discovered large deposits of aluminium in the Bakony Forest, and a company, having a capital of 3,000,000 crowns, has been formed for the working of the ore. This mine is expected to prove the richest in Central Europe.

The Minister of Agriculture has stated that the Government do not own any quantities of basic slag other than the small quantities required from time to time for use on the Ministry's own farm settlements or experiments. No licence is necessary for the importation of ground basic slag.

Steps are now being taken to comply with the provisions of the Women and Young Persons (Employment in Lead Processes) Act, 1920, in War Department workshops or establishments where women or young persons are employed in connection with any process involving the use of lead or lead compounds.

The result of the ballot of shipbuilding trade unions on the acceptance of a reduction of 3s. per week for time workers and 7½ per cent. for piece workers, from last week, and a second 3s. and 7½ per cent. the first week in June, was declared as follows: For acceptance, 45,169; against, 35,913; majority for, 9,256.

In connection with the conference on the means of increasing the thermal efficiency of heat-power plants, which is to be held by the Institution of Mechanical Engineers in London on June 30 and July 1, there will be an exhibition of all kinds of appliances connected with boiler-room economy and the efficient use of steam and internal combustion engines.

At the Royal Albert Hall on Thursday last, the Prince of Wales had conferred on him the honorary degrees of Master of Commerce and Doctor of Science of the University of London.

Speaking at a social gathering in Newcastle of the officials and foremen of the Scotswood Locomotive Works of Sir W. G. Armstrong, Whitworth & Company, Limited, Mr. R. B. McColl, general manager, remarked that only by co-operation and a good spirit and an earnest effort to make the works a success could they hope to build up a big locomotive industry on Tyneside.

At a recent conference held at Sheffield between the Crucible Steel Workers' Association and the Iron and Steel Trades Federation, an application on the part of the employers for a reduction in wages and for a reversion to the "three round day" was discussed at considerable length. The proposed reduction in wages was 17½ per cent. The position is under consideration by the employers.

A joint meeting of British and American engineers will be held in July. On June 29 many distinguished American engineers will arrive in England to express their obligations to the British engineers for the part they played in the war. The American engineers will present Sir Robert Hadfield with the John Fritz Medal, the other recipients of which have been Lord Kelvin, Mr. Edison, and Professor Graham Bell.

The Swedish Government has introduced in the Riksdag a Bill to make a provisional increase in the import duty on industrial products. The duty on goods rated according to weight will be increased by 100 per cent., metals being included in this category. The duty on goods paying *ad valorem* will be raised 30 per cent., including motors, locomotives, tramway cars, scales, etc. It is proposed to retain the increases until July 1, 1922.

By an order in Council dated March 24 the powers and duties of the Ministry of Shipping were transferred to the Board of Trade as from April 1, and the remaining work of that Ministry has now been combined with that of the Marine Department of the Board of Trade. The combined department will be known as the Mercantile Marine Department, and for the present it will be housed in Lake Buildings, St. James' Park.

A paper on the engineering industry by Sir George J. Carter, managing director of Cammell Laird & Company, Limited, was read at a meeting in Liverpool Municipal Central Technical School, under the auspices of the Department of Commerce of the University of Liverpool. In the unavoidable absence of Sir George his Paper was read by Mr. W. H. McMenemey, manager of the engineering department of Messrs. Cammell Laird's Birkenhead yards. The chair was occupied by Mr. Willett-Bruce.

At the recent annual meeting of the Staffordshire Iron and Steel Institute at Dudley, Mr. Joseph Paton (Smethwick) was appointed President for the ensuing year in succession to Mr. Frank Somers, and Mr. F. J. Cook (West Bromwich) was elected Vice-President. The Hon. Treasurer (Mr. James Piper) and the Secretary (Mr. C. B. Pugh) were re-appointed. The annual report stated that the membership was 315, being a decrease of 9. The income amounted to £457, and there was a favourable balance of £182, compared with £100 at the end of the previous year.

Notice is given by the Rates Advisory Committee of the Ministry of Transport that, owing to the present emergency, the public meeting announced for Tuesday last, to consider the general and specific regulations and conditions set out on pages 2-10 and 180-187 of the general proposals of the railway companies for a revision of the general railway classification of goods by merchandise train, has been postponed until 11 a.m. on Tuesday, May 31, when it will be held in the Old Hall, Lincoln's Inn, W.C. The time for lodging objections has been extended until Tuesday, May 24.

The Council of the Institution of Civil Engineers have made the following awards for papers read and discussed during the session 1920-1921: A Telford Gold Medal and a Telford Premium to Mr. George Ellson (London); Telford Gold Medals to Sir Murdoch McDonald (Cairo) and Mr. T. E. Stanton (Teddington); a George Stephenson Gold Medal to Mr. R. G. C. Batson (Teddington); a Watt Gold Medal to Mr. S. A. Main (Sheffield); Telford Premiums to Mr. Algernon Peake (Sydney, N.S.W.), Mr. L. H. Larmuth (London), Mr. H. E. Hurst (Cairo), Professor T. B. Abell (Liverpool), and Mr. Percy Allan (Sydney, N.S.W.).

With reference to the statement in last week's Journal, to the effect that the Chelmsford Town Council had accepted a Belgian tender for cast-iron gas mains, Mr. A. G. Cloake points out that this is erroneous—the contract having been placed with La Société Métallurgique d'Aubrives et Villerupt, of Ardennes, France.

IRON AND STEEL MARKETS.

Pig-Iron.

With business actually suspended, pending a settlement of the miners' dispute, all movements in pig-iron necessarily remain in abeyance, and both buying and selling are restricted to minimum proportions, with only a poor prospect of an early revival of market activities. Production at the furnaces has practically ceased for the time being, and although a few consumers, including foundrymen, are still operating, the gradual exhaustion of fuel supplies is having the inevitable effect of paralysing industry in all departments of the iron and allied trades. As evidencing the stagnation which has overtaken the Tees-side iron trade of late may be instanced the figures of the shipments for April, the total tonnage of exports from the port of Middlesbrough having only amounted to 5,023 tons, of which 320 tons went coastwise to Scotland, and 4,703 tons abroad, as compared with a total of 4,859 tons in March, an increase of 164 tons. Belgium took 2,229 tons, France 1,054 tons, Holland 520 tons, and Sweden 720 tons. With only one firm in the district having any supplies of No. 3 Cleveland foundry iron, it is not surprising that the price should have gone up to 130s., and although at first there was a reluctance to meet the advance buyers recognise that even the higher figure is well below the cost of production, and as there is likely to be a scarcity of foundry iron for some time to come, even if the coal strike be settled promptly 130s. per ton has since been freely paid both for home and export with No. 1 realising 135s. The lower qualities are quite plentiful, and the quotations for these are unchanged at 119s. for No. 4 foundry, 117s. 6d. for No. 4 forge and mottled, and 115s. for white. In a statement issued last week by the Cleveland Ironmasters' Association and the Cleveland Mine Owners' Association, they point out that the members of the Cleveland iron industry, who produce one-third of the total output of the kingdom, are, with their workmen, vitally affected by the negotiations between the parties concerned in the coal dispute, although they now, as heretofore, decline to discuss the merits of the dispute. They wish to enter a strong protest against the payment of any subsidy to the owners or men, as this will only put a tax upon other industries, equally or more in need of help, and postpone the general revival of trade. At its pre-strike price, the cost of coal and coke used equals three-fourths of the selling price of Cleveland pig. In the South Staffordshire area, the output of pig-iron is practically nil, and even when the strike is settled some time must elapse before operations can be resumed. The scarcity is then likely to be acute, as stocks have been greatly reduced, smelters having disposed of them so long as there was an outlet. Reliable prices are not available, but it is probable that when buying is resumed the tendency will be in a downward direction

The Lancashire iron foundries are rapidly coming to an end of their fuel resources, but may be able to get supplies before the blast-furnaces are ready to resume the output of good foundry pig, so that a temporary shortage of this quality iron is still a possibility of the future.

East Coast hematite has been sold recently at the reduced price of 160s. for mixed numbers and 162s. 6d. for No. 1, but makers are still prepared to cut prices for foreign sales, and it is reported that 150s. would be accepted as an export price for mixed numbers, there being no restriction on foreign sales.

Steel.

Complete stagnation will best describe the existing conditions in the steel industry of the country, plants everywhere being reduced to absolute idleness owing to the fuel famine, while both employers and employed are suffering immeasureable loss, and in the last-named category considerable dissatisfaction is expressed with the obdurate attitude of the miners in refusing the very liberal terms upon which work can be resumed. At Sheffield the state of depression is now acute, fuel supplies generally having become exhausted during the five weeks' stoppage of colliery outputs, and only a few works provided with electric power are managing to keep some of the departments partially employed. In the meantime our foreign competitors are taking full advantage of the position to establish a hold on overseas markets formerly supplied by home manufacturers, and though no general revival of demand for steel and its products has yet materialised, the growing menace to British export trade cannot be ignored. As indicating the growing strength of outside competition in the industry, it may be noted that last year works in France produced 19,000 tons of crucible steel and 561,305 tons of electric steel. The total output of steel ingots and castings was just under 3,000,000 metric tons, a third of the total coming from re-annexed Lorraine. Two-thirds consisted of Bessemer basic and more than a million tons of Siemens Martin. There are, however, according to merchant's reports, still some foreign inquiries for steel circulating in the Sheffield market, but these are mostly accompanied by offers of prices considerably below the cost of production in this district. Prospective buyers of steel are, however, in the minority at present, whether for home consumption or export, a general impression prevailing that when the existing labour troubles are subdued prices for all classes of products will approximate nearer to Continental figures. In the Tees-side district steel manufacturers find it almost impossible to seek business in the home market, but shipments abroad are still being made. These orders can be met from stock, and assist in reducing the somewhat heavy accumulations. Still it seems doubtful if there can be more than a practical resumption of work when the miners return, owing to the restricted home demand. Operations at the steelworks in the Glasgow and West of Scotland district have almost entirely ceased. It has been a difficult matter to get the railway companies to lift products from the works sidings, and in most cases it has only been possible on the condition that the manufacturers provided coal for locomotives. Owing to the uncertain labour outlook, business in the markets is very meagre, and with the prospect of cuts in steel prices when conditions are more normal, there is little or no inducement to do anything at present. Even when the miners get back to work some time must elapse before coal is available in sufficient quantities for industrial purposes, and the re-establishment of industry will be a long and tedious process.

Tinplates.

Business in the tinplate market is practically suspended pending some settlement of the coal strike, some idea of the effect of the trade depression in South Wales being expressed in the fact that 16,500 names appear on the registers of the local Employment Exchanges, the majority of whom are engaged in the staple industries. Beyond a few inquiries, more in the nature of "feelers" and efforts to cover commitments in case of a prolonged stoppage, there is practically nothing doing in the way of business, and it is questionable whether merchants in the tinplate market have ever been so idle. Prices, however, remain steady at last week's levels, 28s. per box for the standard make being the general quotation. Appended are the ruling rates:—Cokes, 20 by 14, 28s. to 30s.; ditto quarters, 30s. to 31s.; cokes, 20 by 10, 37s. 6d. to 43s.; ditto 28 by 20, 53s. 6d. to 63s.; ternes, 28 by 30, about 55s. Wasters are in moderate demand.—CW 14 x 20 are scarce at 21s. 9d. CW 28 x 20 are steady at 40s., and CW 14 x 18¾ at 17s. 6d. to 18s. a box, all net, f.o.t. at works.

Finished Iron.

The general position in the finished iron trade indicates little improvement, and except in a few cases where manufacturers hold stocks in hand there is little business passing in the market. Rolling mills in South Staffordshire are now practically idle, while demand has dwindled of late to very small proportions, even marked bar producers having only a limited number of specifications in hand with which to restart work when the coal trouble is ended. Similar conditions are experienced in the case of makers of crown quality bars, most of the producing works having come to a standstill, with stocks all but exhausted. Tubes are still being made, but only on a small scale. Strip makers have disposed of their stocks, and have no means of replacing them, so that if raw material is required it can only be got from the Continent. Quotations for French and Belgian products show an upward tendency in sympathy with the appreciation of the franc. The conclusions arrived at by the Sub-Committee appointed by the Standing Committee on Trusts to report upon any combine existing in the iron and steel products trades appear in a White Paper just issued, and are summarised under three heads. Manufacturers of bolts and nuts are found to be not associated in any organisation which embraces all the trade, and the two associations operating in the Midlands and Lancashire and Yorkshire do not appear to the committee to be exercising any substantial control over either prices or supplies, but as one of the admitted objects is the maintenance of prices a later development may be in the nature of a minimum price policy. Other questions dealt with by the committee apply in the case of cut steel nails and the manufacture of horse nails. The imports of iron, steel, etc., at Hull from abroad during the past week

were :—Iron : Pig, 10 tons (Wilson's and N.E.R. Company), 5 tons (S. Fisher & Company). Bars, etc. : 82 tons (Bleasdale & Company), 1 ton (Hull and Goole Transport Company), 10 tons (Wilson's and N.E.R. Company). Steel : Puddled, 10 tons (Furley & Company) ; blooms, etc., 22 tons (Ellerman's Wilson Line), 23 tons (G. Armitage), 21 tons (Hull and Netherlands S.S. Company), 10 tons (Wilson's and N.E.R. Company) ; zinc sheets, 21 cwt. (Raines & Porter). Goole.—Iron : Pig, 22 tons, 4,402 bars, 305 bundles ditto. Steel : 250 tons rails, etc., 1,553 bars, 104 plates, 72 girders, 352 joists. Spelter : 1,772 ingots (order).

Scrap.

In common with all other branches of the iron and steel industries the scrap metal trade is perhaps more affected by the strike than others, having experienced of late conditions more stagnant than have been recorded at any period in its history. Selling values at the moment are mere guesswork, and with, perhaps, the exception of foundry qualities there is no market for any description of scrap metal. About the only hopeful feature of the position as far as dealers are concerned is that while the production of pig-iron is entirely suspended there are still large accumulations of scrap material in hand, which, when smelting operations are resumed will be immediately available for consumers' needs, and may in that event command better prices than those now quoted in the market. It is, at all events, anticipated that a rise in the present nominal prices will eventuate as soon as buyers reappear in the markets. In the non-ferrous section of the scrap metal trade also business is very quiet, and dealers having already as much stock in hand are reluctant to increase their holdings. The Lancashire dealers' (buying) price for clean copper scrap is about £50 per ton, and for gun-metal £45. Old lead and old zinc are inclined to improve a little, but there is no improvement in yellow brass scrap, of which there is a glut in the market. For ordinary collected brass scrap it is difficult to get more than £25 per ton, but for heavy yellow brass scrap dealers will pay prices varying from £30 to £35 per ton.

Metals.

Copper.—Due probably to the general uncertainty of the political and labour position business in this week's copper market started with a quieter turn, demand for near dates on consumer's account having been on a diminished scale, while buying was much more freely reported for three months' metal. Standard for May was done at £72 10s. to £72 15s. ; June, £71 12s. 6d. Refined sorts were a steady market, electrolytic and wire bars each marking an appreciation of 10s. at £73 to £74. In the States the outside market is a little more animated, but sales are small. The demand is mainly for May shipment, which is being met at 12.50 cents, f.o.b. refinery for electrolytic. Lake copper is steady at 12.75 cents delivered, and castin- copper is easier at 11.75 cents at producer's plant for early shipment. Closing prices :—Cash : Wednesday, £71 10s ; Thursday, £72 10s. ; Friday, £72 10s. ; Monday, £72 5s. ; Tuesday, £72 ; Three months : Wednesday, £70 2s. 6d. ; Thursday, £70 10s. ; Friday, £71 0s. 6d. ; Monday, £71 5s. ; Tuesday, £71.

Tin.—Favourable advices from the East, where buyers' offers at £183 were reported by cable, imparted a steadier tone at the opening of the week's market for tin, followed later by a slight reaction with downward fluctuations in values for both near and forward positions. May offers were marked at £177 10s. to £176 15s. ; June, £178 ; July, £180 ; August, £179 to £178 15s.. English ingots closing 20s. lower at £173 to £174. The weekly return of tin stocks in London warehouses shows a decline of 116 tons at 3,536 tons, with Liverpool stocks decreased 62 tons at 2,536 tons. Swansea remaining unchanged at 66 tons. Closing prices :—Cash : Wednesday, £169 10s. ; Thursday, £176 ; Friday, £177 10s. ; Monday, £176 ; Tuesday, £173 10s. Three months : Wednesday, £172 ; Thursday, £178 10s. ; Friday, £179 15s. ; Monday, £178 ; Tuesday, £175 15s.

Spelter.—Although a fairly active business can be reported in this metal, values have been little affected, both near and forward prices remaining steady round £26, now quoted as settlement basis. June was done at £26 10s. to £26 12s. 6d. ; July, £27 ; and August, £27 5s. Ordinary brands, prompt :—Closing prices : Wednesday, £26 ; Thursday, £26 5s. ; Friday, £26 2s. 6d. ; Monday, £26 ; Tuesday, £26 5s.

Lead.—Opening with a strong and active market, the week's trade in this metal has been well maintained, and with an expected scarcity shortly near future values of good soft pig showed an advance of 25s., with forward dates 2s. 6d. better. May was sold at £23 15s. to £24 ; June, £24 to £23 15s. ; July, £24 ; August, £23 15s. to £24 ; with September at £23 17s. 6d. English closed better at £25.

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

CUPOLA PRACTICE.

To the Editor of The Foundry Trade Journal.

Sir,—The reports of various discussions on the foundry cupola which appear from time to time would lead one to think that there is something uncanny about the average cupola, and that it varies without reason in its performance from day to day. Further discussion leads to details of the cupolas under consideration, and many conflicting opinions on tuyeres and their distance from the hearth, etc., and, finally, a plea for standardised practice.

The only inference from the above is that apparently too many founders think the installing of the melting equipment is a simple matter, and they can save first cost by making it themselves, or who spend too much on the foundry building, and then try and cut the cost on the equipment. The moral follows—if you want a satisfactory melting plant—consult people who specialise in this unit, whose energies and experience has been concentrated on it, or if your cupola is an old one and out of date, replace it.

The difference between a Root's blower and a fan installation does not seem to have been fully appreciated, and is the main source of trouble with people who put down their own plant, although the fan is quite as good as the Root's blower, when the whole unit is designed for that service. The reason why the Root's blower held the field so long was that it gives a constant volume of blast when revolving at a fixed speed, irrespective of resistance in the furnace, thereby simplifying the installation.

With the introduction of high-pressure fans, a more scientific application is necessary, since fans are designed to give a certain volume at a certain pressure, or, in other words, to give a certain volume against a certain resistance which will produce that pressure. Therefore, if the charging hole is low, it is only possible to produce that pressure by adding to the resistance in the stack by an additional resistance in the tuyeres.

In a correctly designed cupola, the whole of the resistance should be produced in the stack, by having a correct height of charging hole. A fan running at a constant speed against a constant resistance will give a constant volume of blast, but any restriction of the tuyeres by slagging will reduce the volume of blast delivered, as it only induces the amount of air it delivers, and the tuyeres must therefore be designed to meet this ; also, any reduction of the resistance in the cupola stack will mean an increased volume of air delivered unless, controlled by a valve between fan and cupola. Further, it should be noted here that any leakage in the pipes, wind-belt, or sight-holes means a high volume and high power loss. Also, the careless opening of a large sight-hole for cleaning the tuyere may seriously overload the fan, which calls for a special design of sight-hole.

Comparing this with a Root's blower or positive blower installation, the above does not apply, and any leakage between the blower and the cupola stack means that a portion of the blast is delivered to the atmosphere against no resistance, thereby reducing the load on the blower, which takes less power to drive, as the blower works at a constant volume under all conditions. Further, with a blower installation any restriction on the tuyere area with slagging will cause the pressure in the wind-belt to rise until the relief valve opens, thereby tending to keep the tuyeres free from slag, and is therefore, as before stated, a simpler working unit to install.

On any other cupola the blast pressure should first be fixed, depending on the diameter and the class of work for which it is to be used, and the height of the charging hole should then be based on this. The volume should be based on the coke consumption required for the class of work for which it is to be used ; the rate of melting is then governed by the pressure of the blast and the area of the melting zone of the cupola.

Mr. Cook gave recently an emperical formula for the pressure and volume of air for cupola practice, but it is difficult to see how this can be of any general value, unless completed with a formula for the height of the charging hole from the centre of tuyeres to give that pressure or resistance. This pressure will vary directly as the head of the coke and iron charges in the stack, and the ascertaining of this by careful experiment would be a valuable factor in cupola work.—Yours, etc.,

"Cupola."

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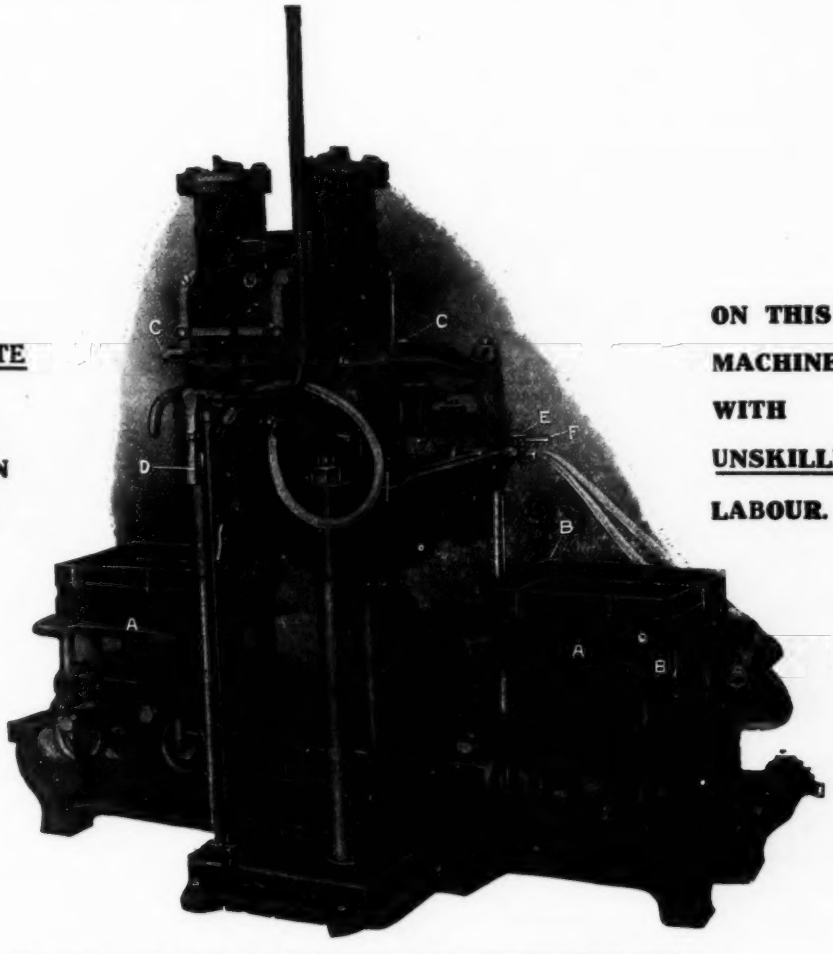

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Gazette.

Messrs. J. Evans and W. Gray, engineers, 137, Arundel Street, Landport, Portsmouth, trading under the style of the Southern General Engineering and Acetylene Welding Company, have dissolved partnership.

The partnership lately subsisting between Messrs. G. D. Gillender, T. Gillender, and T. Wilkinson, brassfounders, under the style of the Northern Brass Foundry Company, Glasshouse Lane, East Street, Gateshead, has been dissolved so far as regards Mr. T. Wilkinson.

Proceedings in bankruptcy have been commenced against Messrs. Wm. Hy. Smerdon, 66, Douglas Road, Handsworth, late Oakdene, Hollywood, King's Heath, and Alf. Hy. Kirby, Solihull Lodge, Yardley Wood Road, Yardley Wood, late trading as Smerdon & Kirby, Dale End, Birmingham, scrap-iron dealers. Adjudicated April 16.

The names of the undermentioned companies are to be struck off the Register of Joint Stock Companies, and the companies dissolved, in three months' time:—Ardila Iron Ore Company, Limited; Burguillos Spanish Iron and General Mining Company, Limited; Minas Geraes (Brazil) Iron Ore Syndicate, Limited; Premier Valve, Limited, Taylor Engineering Company; Trueman Engineering Supplies, Limited; and the Vivero Iron Ore Company, Limited.

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CORKES SAND & GRAVEL PITS,
Bowmans Estate, Crayford, Kent.
Telephone—114, Dartford. Telegrams—Corke, Sandpits, Crayford.

Company News.

Steel Export Company, Limited. — Capital £20,000 in £1 shares.

Sarco Engineering & Trading Company, Limited.—Capital £30,000 in £1 shares.

Chantry's Engineering Works, Limited. — Capital £11,000 in £1 shares (9,500 preference).

Richard Hill & Company, Limited.—Interim ordinary dividend, 5 per cent. per annum for the half-year.

Babcock & Wilcox, Limited.—Dividend of 9 per cent., free of tax, making 16 per cent. for the year 1920.

Sheet Metal Plating Company, Limited. — Capital £5,000 in £1 shares. Registered office: 20, Finsbury Square, E.C.

Hargreaves & Jennings, Limited.—Capital £8,000 in £1 shares, to carry on the business of engineers. Registered office: Railway Foundry, South Boyds Street, Tottington, near Bury.

Aster Engineering Company, Limited.—Final dividend, 2½ per cent., making 7½ per cent., free of tax, for year; reserve for bad debts, £6,000; depreciation, £3,635; carried forward, £40,575.

Blake, Barclay & Company, Limited. — Capital £45,000 in £1 shares, to take over the business hitherto carried on by Blake, Barclay & Company, engineers and millwrights, Greenock. Registered office: Victoria Works, Macdougall Street, Greenock.

Newton, Chambers & Company, Limited.—Profit, £61,555; brought forward, £24,074; interim dividend, 2½ per cent. (free of tax) on preference and ordinary, (£15,323); final dividends, 5 per cent. (free of tax) on preference and ordinary, £30,646; carry forward, £39,660.

Johnson & Phillips, Limited.—Maintenance of buildings, etc., £23,796; profit, £98,405; depreciation, £12,235; income tax and excess profits duty, £24,312; loss on sale of 4 per cent. funding loan written off, £2,776; ordinary dividend, 12½ per cent., less tax; carried forward, £32,113; brought forward, £32,657.

Westinghouse Brake & Saxby Signal Company, Limited.—Final dividend of 2½ per cent., making 5 per cent. for the past year, in cash and 100 per cent. in shares of the Westinghouse Brake Subsidiaries, adding £7,000 to the reserve for contingencies, writing £1,684 off issue expenses, and carrying £14,081 forward.

Personal.

The late Mr. J. Andrews, rolling mills manager to Messrs. A. Harris & Sons, Birmingham, left £3,057.

Mr. Albert Gregory, late of Beachcroft, Gosforth, Northumberland, iron and steel merchant, left £48,347.

Mr. Edward Lisle, late of Oaklands, Tettenhall, Staffs., founder of the Star Engineering Company, Wolverhampton, left £49,679.

Mr. H. Brearley, of Sheffield, has been selected by the Iron and Steel Institute as the recipient of the Bessemer gold medal, which is granted for services in the advancement of iron and steel metallurgy. Mr. Brearley is perhaps best known to the public as the inventor of stainless steel, while his numerous contributions on the important matter of the heat treatment of steel and his publications on this subject are recognised text-books to metallurgists. A self-made man, he is a director of Brown, Bayley's Steelworks, Limited.

MACHINERY (*See also page* 18).

HALL'S Invincible Sand Mixer, capacity 1 ton per hour, 18 in. dia., equal to new, suitable for mixing and preparing all kinds of foundry sands at the lowest cost per ton.—Apply, C .E. V. Hall, 26, Paradise Square, Sheffield.

You save money by buying from us!
Lancashire Boiler, 30 ft. x 8 ft., for 120 lbs. w.p.
Loco. Type Boiler, by Robey, 105 lbs. w.p.
5-ton Overhead Foundry Crane, 30 ft. span.,
35-h.p. Modern Crossley Gas Engine, "U" Type.
20, 30, 40 and 50-h.p. Electric Motors, 460 Vo. D.C.
Blowers, Fans, Engines, etc. Send your enquiries, Harry H. Gardam & Company, Limited, Staines. 'Phone 98.

"LEGGE'S" BELT COMPOUND.
With its addition you will increase your transmission.
Belt slip is minimised and output accelerated to maximum, although the Belt can be run quite slack and easy.
1/7 per lb. 1-lb. Sample Tin, Carriage Paid, 2/6.
F. THOMPSON LEGGE & CO. 16, South Castle St., LIVERPOOL.

SIEMENS' STEEL PROCESS

BOILER, SHIP and BRIDGE PLATES, etc. ANGLES and all forms of Sectional Bars. TYRES and AXLES to all requirements. CASTINGS of all kinds and of Largest Sizes. FORGINGS of every description. BILLETS, BLOOMS, RAILS.

SPECIAL STEEL FOR CONSTRUCTIVE PURPOSES.

The STEEL COMPANY OF SCOTLAND, Ltd.

Head Office: 23, ROYAL EXCHANGE SQUARE, GLASGOW.
Works: HALLSIDE, NEWTON and BLOCHAIRN, GLASGOW.
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UNEQUALLED.

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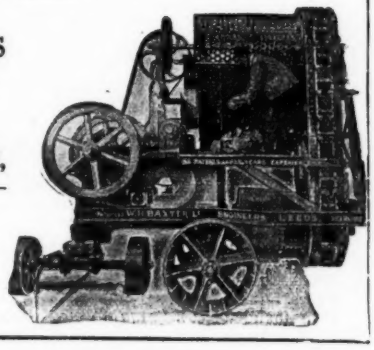

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AND SONS, LTD.

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CLYDEBRIDGE STEEL WORKS, CAMBUSLANG.
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DALZELL STEEL — BOILER BRAND

PLATES, BARS, RAILS and JOISTS.

In Soft, Mild, Medium, High Tensile, H H Tensile, Nickel and Alloy Steel.

DALZELL STEEL — SHIP BRAND

MFM Malleable Ovens

For { Fuel Economy, Efficient Control, Long Life of Pots.

The Manchester Furnaces, Ltd.,
Ashton New Rd.,
MANCHESTER.

O. GOSSELL & SON, LTD.,

110, CANNON STREET, LONDON, E.C.

SPECIALITIES:—

RAILS, TRAM RAILS, STEEL SLEEPERS, STEEL JOISTS to 24 in. deep. CHANNELS, ANGLES, BARS, SHEARED PLATES, FLITCH PLATES to 36 in wide, &c.

BRIDGEWORK and CONSTRUCTIONAL IRONWORK.
SPECIAL STEEL CASTINGS. ROLLING STOCK.

Telephone No.:—CITY 6754. Telegraphic Address:—"GOSSOTTO, LONDON."

WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash	72	0	0
Three months	71	0	0
Electrolytic	73	0	0
Tough	73	0	0
Best selected	73	0	0
Sheets	116	0	0
India	116	0	0
Wire bars	73	15	0
Do. June	73	15	0
Do. July	73	15	0
Ingot bars	73	10	0
H.C. wire rods	81	0	0
Off. aver. cash, Apr.	69	8	11⅞
Do. 3 mths., Apr.	69	9	2⅜
Do. Settlement Apr.	69	8	6⅜
Do. Electro, Apr.	72	16	2⅜
Do. B.S., Apr.	71	6	8
Aver. spot, copper, Apr.	69	7	10½
Do. Electro, Apr.	73	16	8
Solid drawn tubes		15½d.	
Brazed tubes		15½d.	
Wire		12d.	
Yellow metal rods		8½d.	
Do. 4x4 Squares		10½l.	
Do. 4x3 Sheets		10½d	

BRASS.

Solid drawn tubes	13½d.
Brazed tubes	16½d
Rods	12½d.
Sheets to 10 w.g.	11½d.
Wire	11½d.
Rolled metal	11½l.

TIN.

	£	s.	d.
Standard cash	173	10	0
Three Months	175	15	0
English	170	0	0
Bars	175	0	0
Chinese	169	0	0
Straits	183	0	0
Australian	182	0	0
Eastern	183	0	0
Banca	190	0	0
Off. aver., cash, Apr.	164	0	11⅜
Do. 3 mths., Apr.	166	19	4⅝
Do. Sttlment, Apr.	164	0	0
Aver. spot, Apr.	163	19	3½

SPELTER.

	£	s.	d.
Ordinary	26	10	0
Remelted	22	10	0
Hard	16	0	0
Electro 99.9	34	5	0
English	30	0	0
India	21	10	0
Prime Western	27	5	0
Zinc dust	50	0	0
Zinc ashes	6	0	0
Off. aver., Apr.	26	1	5⅝
Aver., spot, Apr.	25	10	7

LEAD.

	£	s.	d.
Soft foreign ppt	24	2	6
English	25	0	0
Off. average, Apr.	20	16	10½
Average spot, Apr.	20	11	9½

ZINC SHEETS.

	£	s.	d.
Zinc sheets, spot	36	0	0
Do. V.M. ex. whf	36	0	0
Do. ppt., f.o.b., N.Y.		—	
Dutch	35	0	0
Boiler plates	32	10	0
Battery plates	32	0	0

ANTIMONY.

	£	s.	d.
English regulus	37	0	0
Special brands	42	0	0
Chinese	25	0	0
Crude	18	10	0

QUICKSILVER.

	£	s.	d.
Quicksilver	11	2	6

FERRO-ALLOYS AND STEEL-MAKING METALS.

Ferro-silicon—	
45/50%	£17 0 0
75%	£24 0 0
Ferro-vanadium—	
35/40%	24/- lb. va.
Ferro-molybdenum—	
70/80%	10/- lb. mo.
Ferro-titanium—	
23/25%, carbonless	1/6 lb.
Ferro-phosphorus, 20/23%	£32
Ferro-tungsten—	
80/85%, carbon free	1/10 lb.
Tungsten metal powder—	
98/99%	2/3 lb.
Ferro-chrome—	
4/6% car.	£37 0
6/8% car.	£36
8/10% car.	£35 10
Ferro-chrome—	
Max. 2% car.	£84
Max. 1% car.	£100
Max. 0.75% car.	£115
65/75%, carbonless	2/9 lb.
Nickel—99·8%, cubes or pellets	£195
Cobalt metal—97%	17/6 lb.
Aluminium—98/99%	£150
Metallic Chromium—	
98/99%	6/6 lb.
Ferro-manganese—	
76/80%, loose	£22
76/80%, packed	£23
76/80%, export	£19
Metallic manganese—	
98/99%, carbonless	3/- lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

	s.	d.
Finished bars, 14% tungsten	3	0
Finished bars, 18% tungsten	3	9
Scrap pieces		5d.
Turnings and swarf		3d.

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares 3 in. to 8 in. inclusive 4d. lb.
Rounds and squares under ½ in. to ¼ in. 3d. lb.
Flats under 1 in. by ⅜ in. to ¼ in. by ¼ in., and all sizes over four times in width over thickness 3d. lb.
Bevels of approved sizes and sections 6d. lb.
If in coils 3d. lb.
Packing 4s. cwt
Bars cut to length 10% extra

Scrap from high-speed tool steel—

Scrap pieces	5d.
Turnings and swarf	3d.

Per lb. net, d/d steel makers' works.

SCRAP.

	£	s.	d.
South Wales—£ s. d.			
Heavy Steel	3	0	0
Bundled steel & shearings	3	0	0
Mixed iron & steel 1 0 0	3	10	0
Heavy cast iron	3	15	0
Good machinery for foundries	5	10	0
Cleveland—			
Heavy steel	2	10	0
Steel turnings	2	7	6
Cast-iron borings	2	7	6
Heavy wrought iron piling	3	10	0
Bundling scrap	4	5	0
Cast-iron scrap	5	10	0
Lancashire—			
Cast iron scrap	6	0	0
Heavy wrought	3	0	0
Steel turnings	1	10	0
London—			
Copper (clean)	49	0	0
Brass (clean)	28	0	0
Lead (less usual draft)	16	10	0
Tea lead	14	10	0
Zinc	13	0	0
New aluminium cuttings	75	0	0
Braziery copper	39	0	0
Gun metal	45	0	0
Hollow pewter	130	0	0
Shaped black pewter	75	0	0

PIG-IRON.

N.-E. Coast—	
Foundry No. 1	125/-
Foundry No. 3	120/-
Forge No. 4	117/6
Mottled	117/6
Hematite No. 1	162/6
Hematite M/Nos.	160/-
Midlands—	
Staffs. common	145/-
„ part-mine forge	160/-
„ „ foundry	170/-
„ Cold blast	320/-
„ basic	140/-
Northants forge	140/-
„ foundry No. 3	147/6
„ basic	140/-
Derbyshire forge	150/-
„ foundry No. 3	160/-
„ basic	150/-
Scotland—	
Foundry No. 1	170/-
„ No. 3	165/-
Hematite M/Nos.	180/-
Sheffield (d/d district)—	
Derby forge	155/-
„ foundry No. 3	160/-
„ basic	155/-
Lincs. forge	160/-
„ foundry No. 3	170/-
„ basic	162/6
E.C. hematite	173/-
W.C. hematite	196/-

All d/d in the district.

Lancashire (d/d eq. Man.)—	
Derby forge	—
„ foundry No. 3	170/-
Northants foundry No. 3	—
Cleveland foundry No. 3	—
Staffs. foundry No. 3	—
Lincs. forge	172/6
„ foundry No. 3	177/6
Summerlee foundry	193/-
Glengarnock foundry	193/-
Gartsherrie foundry	193/-
Monkland foundry	193/-

FINISHED IRON & STEEL.

	£	s.	d.
Iron—			
Bars (cro'n)	19	0	0
Angles	19	10	0
Tees to 3 united ins.	20	0	0
Nut and bolt	19	0	0
Hoops	23	0	0
Marked bars (Staffs.)	27	10	0
Gas strip	22	0	0
Bolts and nuts, ⅜ in. × 4 in.	38	0	0
Steel—			
Ship plates	19	0	0
Boiler plates	25	0	0
Checquer plates	20	0	0
Angles	17	10	0
Tees	18	10	0
Channels	18	0	0
Joists	17	10	0
Rounds, ⅜ in.–3-in.	14	10	0
Rounds, 3 in.–5½ in.	13	10	0
Flats, 5 in.–8 in.	15	0	0
Flats over 8 in.	13	10	0
Rails, heavy	15	0	0
Fishplates	20	0	0
Hoops	17	10	0
Black sheets, 24 g.	20	10	0
Galv. cor. sheets, 24 g.	22	0	0
Galv. fencing wire, 8 g. plain	26	0	0
Rivets, ½ in. dia	27	0	0
Billets, soft	13	0	0
Billets, hard	14	0	0
Sheet and tin bars	13	0	0

PHOSPHOR BRONZE.

Rolled.	Per lb. s.	d.
¼ in. to 1 in. wide	1	9½
1 in. to 1½ in. wide	1	9½
1½ in. to 2 in. wide	1	7½

Strips.	s.	d
2 in. to 6 in. to 26 S.W.G.	1	7½
6 in. to 12 in. to 26 S.W.G.	1	7½

Sheets.	s.	d.
12 in. to 18 in. to 24 S.W.G.	1	7½
18 in. to 24 in. to 24 S.W.G.	1	8½
24 in. to 30 in. to 20 S.W.G.	1	9½
30 in. to 36 in. to 16 S.W.G.	1	9½
36 in. to 42 in. to 16 S.W.G.	1	10½

Extras.

For Gauge: Any width up to 36 in. wide, ¼d. per lb. per thinner gauge.

Drawn Rods.	s.	d.
¼ in. to ½ in. dia. in random lengths; ⅝ in. to 1¼ in. dia. in random lengths	1	8
Over 1¼ in. to 1⅝ in.	1	8
Tubes—basis price	1	9½

Delivery 2 cwt. free to any town.

10% phosphor copper, £40 above price of B.S.

15% phosphor copper, £50 above price of B.S.

Phosphor tin (5%), £30 above price of English ingots.

Charles Clifford & Son, Limited, Birmingham.

NICKEL SILVER, SHEET METAL, WIRE AND TUBES.

	Per lb.
Ingots for raising	1/1 to 1/7
Rolled—	
To 9 in. wide	1/8½ to 2/2½
To 12 in. wide	1/9 to 2/3
To 15 in. wide	1/10 to 2/4
To 18 in. wide	1/11 to 2/5
To 21 in. wide	2/- to 2/6
To 24 in. wide	2/1 to 2/7
Ingots for spoons and forks	1/1 to 1/7
Ingots rolled to spoon size	1/4 to 1/10
Wire round—	
3/0 to 10. G.	1/11 to 2/6

with extras according to gauge.

AMERICAN IRON & STEEL.

At Pittsburgh unless otherwise stated.

	Dols.
No. 2X foundry, Phila.	26.26
No. 2 foundry Valley	24.50
No. 2 foundry, Birm.	23.00
Basic	24.96
Bessemer	26.96
Malleable	26.96
Grey forge	25.46
Ferro-manganese 80 % delievred	90.00
Bess. rails, h'y, at mill	45.00
O.-h. rails, h'y, at mill	47.00
Bess. billets	37.00
O.-h. billets	37.00
O.-h. sheet bars	39.00
Wire rods	48.00

	Cents.
Iron bars, Phila.	2.35
Steel bars	2.10
Tank plates	2.20
Beams, etc.	2.20
Skelp, grooved steel	2.20
Skelp, sheared steel	2.20
Steel hoops	2.75
Sheets, black, No. 28	4.00
Sheets, galv., No. 28	5.00
Sheets, blue an'l'd, 9&10	3.10
Wire nails	3.25
Plain wire	3.00
Barbed wire, galv.	4.00
Tinplate, 100-lb. box	$6.25

COKE.

Welsh foundry	67/6
„ furnace	55/-
Durham & North. foundry	70/-
„ furnace	42/6
Other Districts, foundry	77/9
„ furnace	45/-

SWEDISH IRON.

Bars, hammered basis sizes Basis price £35 to £37

Rolled Ordinary—Assortment ..	£ 22	s. d. 10 0
Nail Rods—Square, round and flats ..	to 23	10 0
Keg Steel } about Faggot Steel } £40	Prices nominal.	

Blooms—
Single welded .. £16 to £18

Billets—
Single and double welded .. £18 to £23

Pig-Iron—
Grey, white or mottled ..£12/10 to £14

Prices are without engagement. All quotations are f.o.b. Gothenburg, net cash against documents there.

TUBES.

	Up to and incl. 2 in.	Over 2 in.
Gas ..	−15%	−20%
Water ..	− 5%	−11¼%
Steam ..	+ 6¼%	− 1¼%

TINPLATES.

I.C. Cokes,	20×14, box	28/–
,,	28×20, ,,	53/6
,,	20×10, ,,	37/6
,,	18¾×14, ,,	30/6
I.X.	,,	71/–
I.X.X.	,,	90/–
F.C.B.Y.	21×13⅝ ,,	50/6
C.V.B.G.	16¼×15, ,,	50/–
I.C.W.	20×14, ,,	21/9
,,	28×20, ,,	40/–
,,	20×10, ,,	28/6
,,	18¾×14, ,,	17/6
Terneplates,	28×20, ,,	55/–

DAILY FLUCTUATIONS.

Standard Copper (cash).

	£	s.	d.		
May 4	71	10	0	inc.	5/–
,, 5	72	10	0	,,	20/–
,, 6	72	10	0	No change	
,, 9	72	5	0	dec.	5/–
,, 10	72	0	0	,,	5/–

Electrolytic Copper (Cash).

May 4	72	0	0	No change	
,, 5	72	10	0	inc.	10/–
,, 6	72	10	0	No change	
,, 9	73	0	0	inc.	10/–
,, 10	73	0	0	No change	

Standard Tin (cash).

May 4	169	10	0	inc.	30/–
,, 5	176	0	0	,,	130/–
,, 6	177	10	0	,,	30/–
,, 9	176	0	0	dec.	30/–
,, 10	173	10	0	,,	50/–

Tin (English Ingots)

May 4	166	10	0	inc.	50/–
,, 5	172	0	0	inc.	110/–
,, 6	174	0	0	,,	40/–
,, 9	173	0	0	dec.	20/–
,, 10	170	0	0	,,	60/–

Zinc Sheets (spot).

May 4	36	0	0	No change
,, 5	36	0	0	No change
,, 6	36	0	0	No change
,, 9	36	0	0	No change
,, 10	36	0	0	No change

Spelter (ordinary).

May 4	26	0	0	inc.	12/6
,, 5	26	5	0	,,	5/–
,, 6	26	2	6	dec.	2/6
,, 9	26	5	0	inc.	2/6
,, 10	26	10	0	,,	5/–

Lead (English).

May 4	23	10	0	inc.	7/6
,, 5	23	10	0	No change	
,, 6	23	15	0	inc.	5/–
,, 9	25	0	0	,,	25/–
,, 10	25	0	0	No change	

SHROPSHIRE IRON Co., Ltd.

Works:—
Hadley, Shropshire.

London: 10, Bush Lane, Cannon St., E.C.4.

Telegrams:—
Sun, Wellington, Salop.
Sunbrand (Cannon), London.

Telephone:—
11 Wellington, Salop.
5959 Central.

BARS, HOOPS, SECTIONS & WIRE
in IRON, STEEL, COPPER and BRONZE.

Galvanised Telegraph, Telephone, Cable and Trolley Wire
To all Specifications.

Contractors to H.M. Government (Admiralty, G.P.O., India Office, War Office, Colonies), English and Foreign Railways, &c.

BEST H. C. COPPER & BRONZE WIRE a speciality.

Medals:—Sydney (Bronze) 1879, New Zealand (Gold) 1882, Liverpool (Silver) 1886, Adelaide (Gold) 1887, Franco-British Grand Prix (Highest Award) 1908.

ROBERT HEATH & LOW MOOR, LIMITED,
Stoke-on-Trent.

B.B.H. IRON.
At works.
BARS, ANGLES, TEES and PLATES.

R.H. ♔ IRON.
Delivered F.O.B. Liverpool.
BARS, ANGLES, TEES and PLATES.

HOOPS delivered F.O.B. Liverpool.

IRON
R.D. ♔
RAVENSDALE (Best)

MILD STEEL (up to 2in. wide)
Marked
"HEATH'S SOFT STEEL."

Prices on Application.

WILLIAM JACKS & COMPANY,
5, EAST INDIA AVENUE, LONDON, E.C.3.

Telegrams: ALKALIZE, BIRMINGHAM.
Telephone: CENTRAL 1175 & 1176
Birmingham Office:
18, BENNETT'S HILL.

Telegrams: ALKALIZE, LONDON.
Telephone: 7860 AVENUE (3 lines.
Head Office:
5, EAST INDIA AVENUE, London, E.C.

REGISTERED TRADE MARK

PIG IRON.

Scotch, Middlesbro,' Hematite, Basic, Specials, &c., &c.

TIN — SPELTER — CHROME
COPPER — ANTIMONY—MANGANESE.

WILLIAM COLVIN & COMPANY,

ROYAL EXCHANGE, MIDDLESBROUGH.

93, HOPE STREET, GLASGOW.

SITUATIONS VACANT AND WANTED.

ADVERTISER, Englishman, 37 years of age, engineering training, expert in quantity production of iron and steel castings for motor transport and general engineering, and in steel-making for foundries, forges, and rolling mills (best British and Continental practice), open to engagement as Foundries' or Steelworks' Manager, or would be responsible to enterprising firm for the design, equipment, and operation of new works or the development of old works in this country to meet foreign competition; highest references.—Box 742, Offices of the FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

FOUNDRY MANAGER desires change, wide modern experience, Cast and Malleable Irons Crucible Steel (mild), Gunmetal, Aluminium, etc.; expert experience of modern moulding machines (all types) and organisation; can get results; able to introduce new clients, or would consider representing up-to-date firm in London area; age 41; energetic, industrious, of good address, and reliable.—Box No. 734, Offices of the FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

PATENTS.

ADVICE and Handbook Free. — KING'S PATENT AGENCY, LIMITED, Director, B. T. King, Reg. Patent Agent, 146a, Queen Victoria Street, E.C.4.

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ORDERS WANTED for small Machine-made Castings in Brass, Gunmetal, Phosphor, or Manganese Bronze. Also Castings any size up to one ton in weight. Prompt delivery.—JAMES G. CROWTHER, Paradise Street Brass Foundry, Sheffield.

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3 ,,	⅞ in. ,,	
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MACHINERY.

TURN TO THE B.W.S. ANNOUNCEMENT, PAGE 12.

ONE 34-in. Roots' Blower, by Thwaites and Carbutt, 9-in. outlet, excellent condition.—Bruntons (Sudbury, 1919), Limited, Stour Valley Ironworks, Sudbury, Suffolk.

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